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EVA METRO SEDAN ELECTRIC PROPULSION SYSTEM TEST AND EVALUATION.(U)
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U.S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT COMMAND
FORT BELVOIR, VIRGINIA 22060

EVA METRO SEDAN ELECTRIC PROPULSION SYSTEM

TEST AND EVALUATION

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September 1979

Prepared for

Department of Energy
Conservation and Solar Applications
Office of Transportation Programs
Washington, DC 20545

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER 9
4. TITLE (and Subtitle) 6 EVA METRO SEDAN ELECTRIC PROPULSION SYSTEM TEST AND EVALUATION		5. TYPE OF REPORT & PERIOD COVERED In-House Technical Report. Jan 78 - Sep 79
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) 10 Eberhart/Reimers		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS US Army Research & Development Command Electrical Equipment Division, Electrical Power Laboratory, DRDME-EA, Ft. Belvoir, VA 22060		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS Interagency Agreement EC-77-A-31-1042 dated 13 May 1977
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE 11 September 1979
		13. NUMBER OF PAGES 275
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) 12 291		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited

15 DOE-IAA-EC-77-A-31-1042

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Electric Propulsion
Electric Dc Motor
Electric Passenger Vehicle
Dc Two Phase Chopper
Dc Motor Controller

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report provides the procedure and results of the performance evaluation of an EVA Metro Sedan propulsion system. Data is provided for the automatic transmission, solid state dc motor controller and the dc motor as well as the entire propulsion system. Algorithms used on the automatic data acquisition system are included.

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I. SUMMARY

This report provides the procedure and results of the performance evaluation of the EVA Metro Sedan (car #1) variable speed dc chopper motor drive and its three speed automatic transmission. The propulsion system for a battery powered vehicle manufactured by Electric Vehicle Associates, Valley View, Ohio, was removed from the vehicle, mounted on the programmable electric dynamometer test facility #2, located at the premises of the Electrical Equipment Division, Bldg 326, and evaluated with the aid of a HP 3052A Data Acquisition System under the direction of the U.S. Army Mobility Equipment Research and Development Command (MERADCOM), Fort Belvoir, Virginia, as part of a Department of Energy (DOE) Interagency Agreement EC-77-A-31-1042, dated 13 May 1977. The report furnishes performance data for the automatic transmission, the solid state dc motor speed controller, and the dc motor in the continuous and pulsating dc power mode, as derived on the dynamometer test facility, as well as the entire propulsion system.

The purpose of this project was to evaluate this concept and the system's components in terms of commercial applicability, maintainability and energy utility to establish a design base for the further development of this system or similar propulsion drives. Compilation of data with the HP 3052A Data Acquisition System made it possible to complete individual test runs in typically 20 to 30 seconds, yielding up to 36 direct read-outs for each test run and an additional 43 calculated data points. A comprehensive analysis of system and component performance was made over the entire speed, load torque and power profile which was interpreted in terms of 5 constant power profiles @ rated power, 0.75; 0.50; 0.25; and 1.25 times rated power of the motor. The incorporation of this data acquisition system into a programmable electric dynamometer test facility, possibly the first of its kind, has increased the quality, accuracy and speed of data acquisition heretofore not readily available in industry.

The propulsion system of the EVA Metro Sedan is powered by sixteen 6-volt traction batteries, Type EV 106 (Exide Battery Mfg. Co.). A thyristor controlled cable form Pulsomatic Mark 10 controller, actuated by a foot throttle, controls the voltage applied to a dc series field motor, rated at 10 HP @ 3800 RPM (Baldor Electric Co.). Gear speed reduction to the wheel is accomplished by the original equipment three speed automatic transmission with torque converter (Renault 12 Sedan). The brake consists of a power assisted, hydraulic braking system with front wheel disk and rear drum. An ability to recuperate electric energy with subsequent storage in the battery power supply is not provided.

Constant speed performance data, as derived from dynamometer test runs, are shown in Table 1 and Figure 1.1, whereby symbols and unit abbreviations are presented at the top of Table 1.

II. ACKNOWLEDGEMENTS

The author wishes to thank Mr. James H. Ferrick for the development of the software and data acquisition; Carl J. Heise for the design of the test stand; and, George M. Sisk and Andrew A. Thompson for their technological support to establish the test facility and to verify data.

The battery test was performed by E. E. Moyer of E²M Engineering Services, while the evaluation of the "Marshall" battery charger was performed by E. J. Dowgiallo, Jr., and other members of the Electro-Chemical Division, MERADCOM, Fort Belvoir, Virginia.

Table 1: EVA Constant Speed Vehicle Performance Data

Motor Data		Transmission		Propulsion Sys Loss		EVA Performance		
Speed NTR RPM	Torque TMOT N-M	Slip Freq HZ	Gear Ratio :1	Power Loss WLEVA WL/W	Energy Loss JLEVA JL/J/KM	Required Energy JEVA KWH/KM	Vehicle Speed KM/H	Eff'cy EFFEVA %
4000	17.8	1.95	8.52	1.37	103.0	0.212	48.179	42
3200	22.3	2.15		1.49	140.7	0.292	38.104	40
2560	27.8	2.1		1.44	171.4	0.355	30.201	41
2047		2.35		2.78	423.2	0.717	23.649	26
1637		2.7		3.41	670.3	0.910	18.302	23
1303				4.29	1090.6	1.176	14.157	19
1044				5.35	1760.1	1.522	10.944	16
839				6.22	2665.7	1.853	8.400	14
			1					
4000	17.8	2.2	5.21	1.37	63.1	0.131	77.886	42
3200	22.3	2.35		1.55	91.0	0.187	61.596	39
2560	27.8	2.15		1.37	101.1	0.209	48.950	42
2047		2.15		2.66	247.6	0.423	38.621	27
1637		2.3		3.27	389.9	0.529	30.184	23
1303				4.13	634.2	0.684	23.458	20
1044				5.15	1016.3	0.879	18.243	16
839				5.99	1527.2	1.062	14.115	14
			2					
4000	17.8	2.0	3.65	1.94	67.4	0.140	103.165	34
3850	18.5	2.05		1.94	67.9	0.141	98.504	34
3200	22.3	2.2		1.87	86.0	0.177	78.671	35
2560	27.8	2.4		2.27	138.4	0.287	58.930	31
2047				2.97	242.2	0.412	44.064	25
1637				3.51	391.8	0.532	32.189	22
1303		2.85		4.38	800.4	0.866	19.662	19
1044				5.41	1601.4	1.293	12.160	16
839				6.58	3803.5	2.175	6.223	13
			3					

NTR = Motor speed (NMOT) at transmission input.
TMOT = Motor shaft torque.
SLIP = Transmission slip frequency referred to its input.
WLEVA = System power loss per unit power delivered to the wheel in watts.
JLEVA = System energy loss per unit energy delivered to the wheel in joules.
JEVA = Energy consumption per KM distance travelled.
O = Encircled numbers indicate transmission gear speed selector.

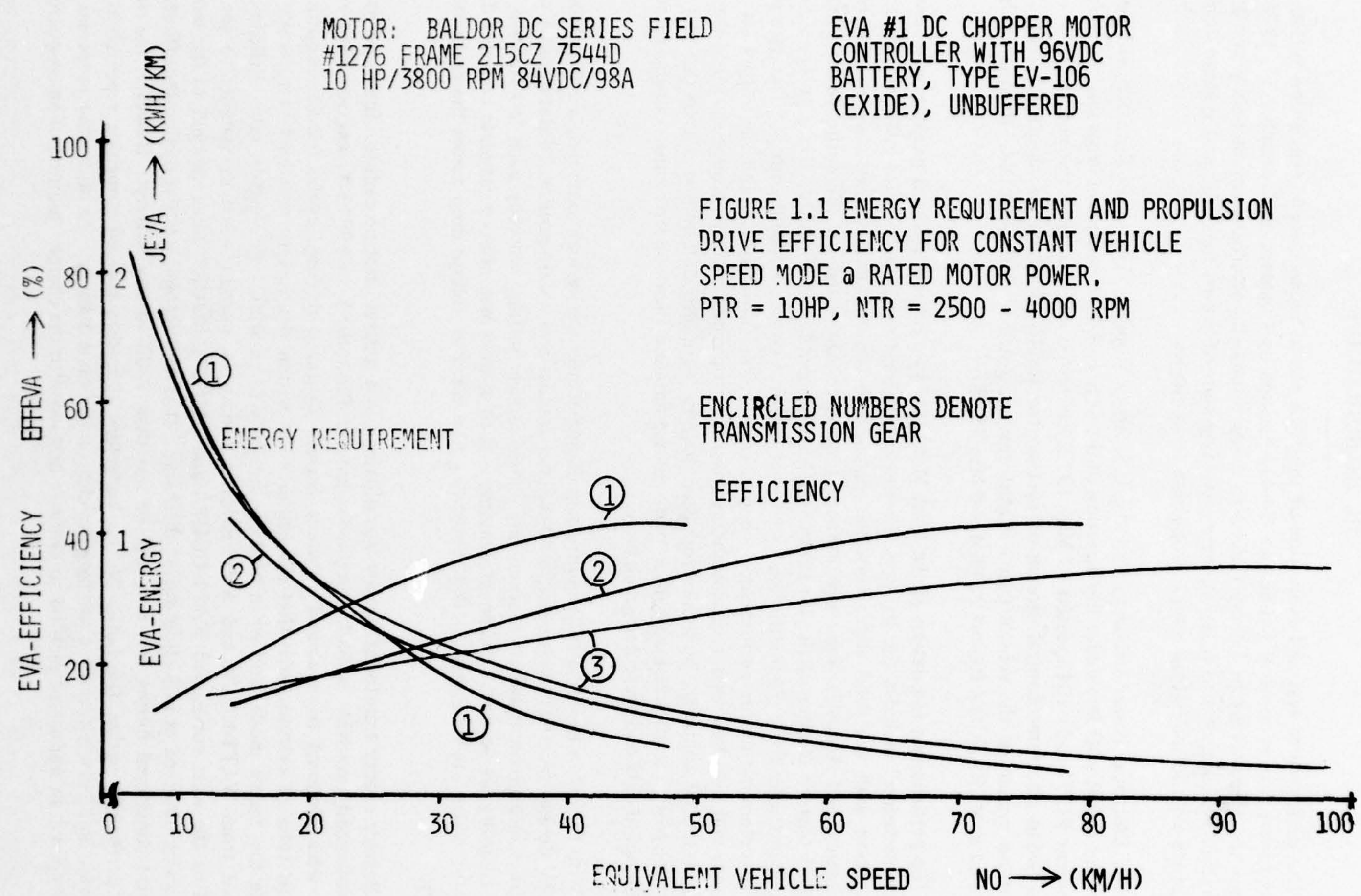


FIGURE 1.1 ENERGY REQUIREMENT AND PROPULSION DRIVE EFFICIENCY FOR CONSTANT VEHICLE SPEED MODE @ RATED MOTOR POWER. PTR = 10HP, NTR = 2500 - 4000 RPM

III. INTRODUCTION

The performance test and evaluation of the EVA Metro Sedan electric propulsion system presented in this report is in support of Public Law 94-413 enacted by Congress on September 17, 1976. The law requires the Department of Energy (DOE) to develop data characterizing commercially available electric and hybrid vehicles, and to foster programs yielding state-of-the-art hardware and systems configurations to improve electric and hybrid vehicle propulsion technologies.

The Electrical Power Laboratory of the U.S. Army Mobility Equipment Research and Development Command (MERADCOM) under the direction of the Office of Transportation Programs, DOE, Interagency Agreement EC-77-A-31-1042, dated 13 May 1977, has tested and evaluated the performance of the EVA Metro Sedan electromechanical propulsion system, the results of which are reported herein. This is the propulsion system of the vehicle that was performance tested by MERADCOM. Results of that test are presented in MERADCOM Report 2244, dated May 1978.

The performance evaluation of the EVA Metro Sedan electromechanical propulsion system or "electric transmission" includes the battery, the three speed automatic gear speed reducer, the dc motor in conjunction with the solid state controller panel, and the on-board battery charger. Electromagnetic Interference and Acoustic Noise performance tests were conducted for the entire vehicle, including the on-board battery charger at the MERADCOM Environmental Test Facility. Data points were taken at the dynamometer for a parametric load profile at multiple constant speed settings. The data points were used to determine motor performance when energized from a dc source; and the impact on motor performance and heat loss when receiving energy from the propulsion battery through the dc controller. Watt-losses in the dc controller and the propulsion battery were also determined during this test run. The constant speed, parametric load torque performance data are then converted into constant power/torque variable speed data and presented graphically.

With the aid of the HP 3052A multi-channel data acquisition system containing a 225 K byte memory, a digital dc and true RMS voltmeter, a 30-channel scanner and a data printer, 36 data points were logged by direct measurement for each speed and motor torque setting, whereby each test run was completed after typically 24 seconds. When programmed, such system was able to calculate complex data points, many of which are described in this report, e.g.: a resistive voltage drop across the series field of a dc motor.

Battery energy transfer efficiency was obtained in a separate test procedure. Inasmuch as an EV106 was not readily available, a similar propulsion battery, Prestolite Model 9915-X, was used for test purposes. Data were obtained from several constant current discharge/recharge cycles for five arbitrarily chosen specific rates of current, such that the gas pressure within the battery remained at typically 0.5" H_2O during the charge mode, and when bled continuously at an arbitrarily constant rate. Efficiency was calculated from WATT-HOUR and AMPERE-HOUR data vs. current when discharging to the inflection point of the watt curve, and WATT-HOURS and AMPERE-HOURS when charged to the same ampere-hour value obtained at inflection during discharge. It is well recognized that coulombic efficiency, which was not considered during this test, will be less than 100% in any battery. However, the rudimentary tests performed within the limits of the budgetary allocation showed surprising repeatability between batteries and between various discharge cycles of the same battery. As such, the proposed procedure is considered an important method to evaluate and monitor the charge condition of an on-board multi-cell

battery assembly. The results of these tests, therefore, are considered of potential interest to the system designer, and, hence, have been included in this report for this very reason.

IV. OBJECTIVE

The purpose of this test and evaluation program is to provide complete characterization of the propulsion system and its building blocks since performance data are unavailable from commercial sources. Performance data of interest are:

Transmission
- Power transfer profile over speed range
- Efficiency
- Power-Loss/Motor Torque applied at input

DC Motor
- Voltage-current characteristics
- Efficiency
- Power-Loss/Shaft Torque
- Performance degradation when operating in the pulsating dc power mode

DC Controller
- Transient Waveform analysis
- Efficiency
- Power-Loss/Motor Torque

Battery
- Energy requirements vs. power-speed profile of motor, vehicle
- Energy Losses when discharging
  - dc current
  - pulsating current
- Power transfer efficiency
- Losses when recharging
- Energy requirement vs. recharge current
- Battery performance test

Propulsion System
- Efficiency, electric drive only w/o transmission
- Power-Loss/Motor Torque vs. speed
- Required Energy/Km travel vs. speed of the vehicle

EVA Metro Sedan
- Electromagnetic Interference test
- Noise test

V. DESCRIPTION OF PROPULSION SYSTEM

The electric propulsion system for the EVA Metro Sedan comprises sixteen 6-Volt batteries, Exide EV 106; a thyristor controlled dc chopper type motor controller, Cableform Pulsomatic Mark 10; a dc series field motor rated 10 HP @ 3800 RPM/min, Baldor Electric Company, motor identification plate not furnished; and the original equipment mechanical transmission with torque converter, three forward positions and one reverse. Activation of the accelerator foot pedal controls the on-off conduction cycle of the controller's main thyristor and thus the power flow to the propulsion motor. The motor in turn drives the torque converter of the mechanical transmission which in turn drives an automatic transaxle. The gear shifting of the transaxle in its three forward speeds is controlled by two solenoids with electrical energizing coils, while the reverse gear is activated mechanically. The shifting of the transaxle is accomplished electrically by comparison of motor speed and its current, and a pre-set gear shift selector. Power transfer to the wheel increases commensurably with accelerator pedal travel. However, braking is accomplished solely by mechanical means. No regenerative braking is provided.

VI. PROPULSION SYSTEM RELIABILITY

The car was received after road testing and general use as a shuttle vehicle. It had 2332 miles registered on the odometer when the propulsion system was removed from the vehicle. Major problems were encountered which either delayed, or required repetition of component testing. Initially, it was necessary to repair the broken seals of the drive shaft, shown in Figure 6.1. These seals had to be slipped over the flexible "Knuckle" joint with a special tool to avoid damage during mounting.

During testing it was learned that the original equipment motor winding bars were soft soldered to the commutator bars. Heat in the motor and centrifugal force caused disintegration of the solder joints, partial open circuiting of commutator bars, and deposition of solder pebbles across the field winding, end bell and the air-gap. This is shown in Figures 6.2 through 6.6. The motor was replaced with a hard soldered unit, Baldor Electric Company Motor Frame 215 CZ 7544D, Specification 29 1755 11211, 10 HP, 3800 RPM, 84 CDC, 98A, Serial No. 1276. The entire evaluation of the electric propulsion system was performed with this motor.

Because of the circuit configuration the chopper controller developed an unusually large power loss resulting in excessive heating. Contact areas in the contactor are badly burnt. The contactor appears underrated for its task.

The battery charger was considered difficult to use because of its lack of input/output/insulation, and difficulties to maintain a constant charge level across the battery assembly because of its 15 A dc current capacity. The unit was replaced with an in-house charger, consisting of a generator-rectifier unit with field control and able to furnish up to 300 A dc charge current.

Adequate fusing of the solid state controller in its present form is considered virtually ineffective because of the very high peak to average current amplitude ratios at low motor speed. The fuse can be matched only for only one condition, and will not satisfy the requirements for the other current mode, as described in the literature (Ref. 1).

Figure 6.1. Broken seal of drive shaft.

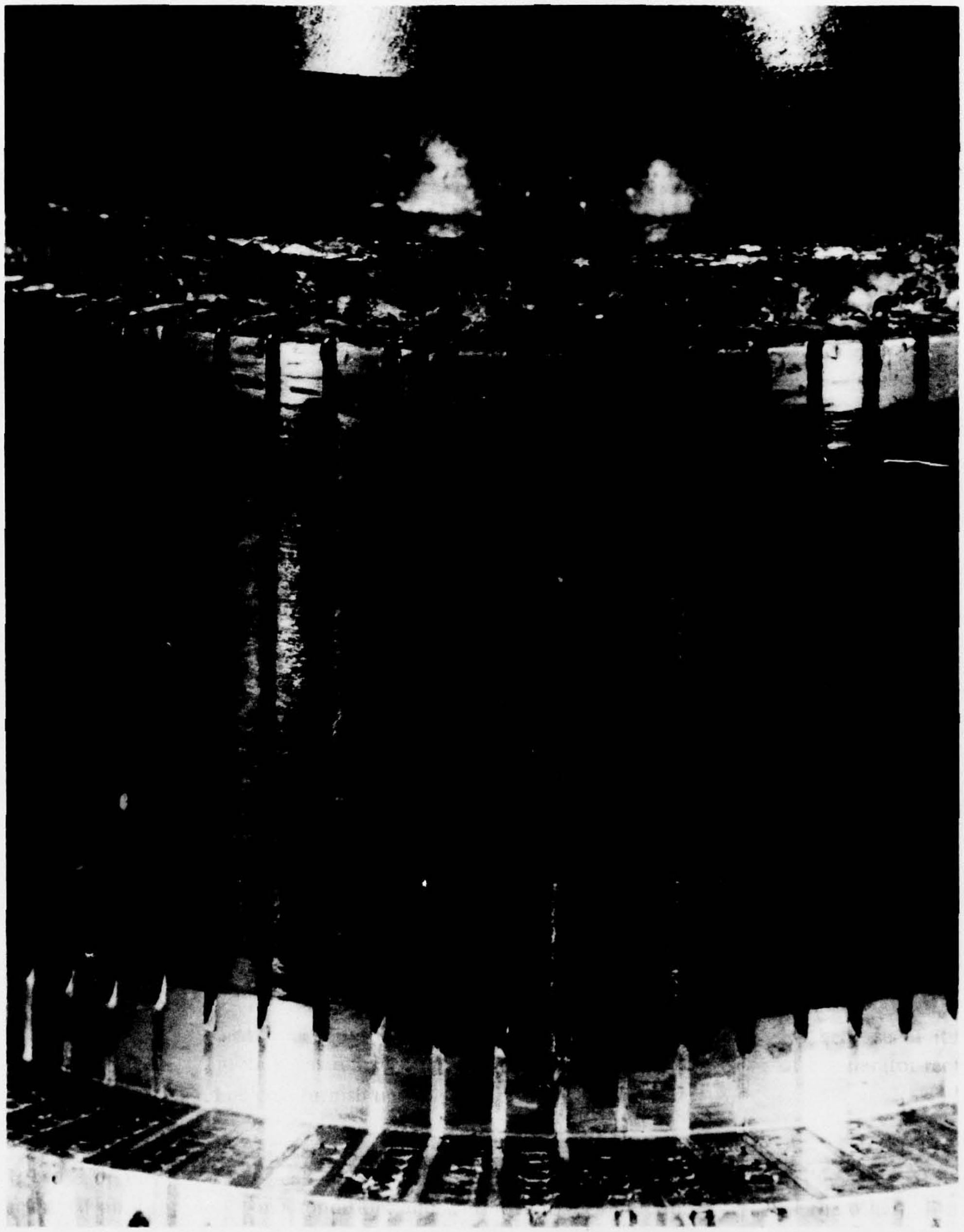


Figure 6.2. Motor damage to commutator caused by disintegration of soft solder joints.

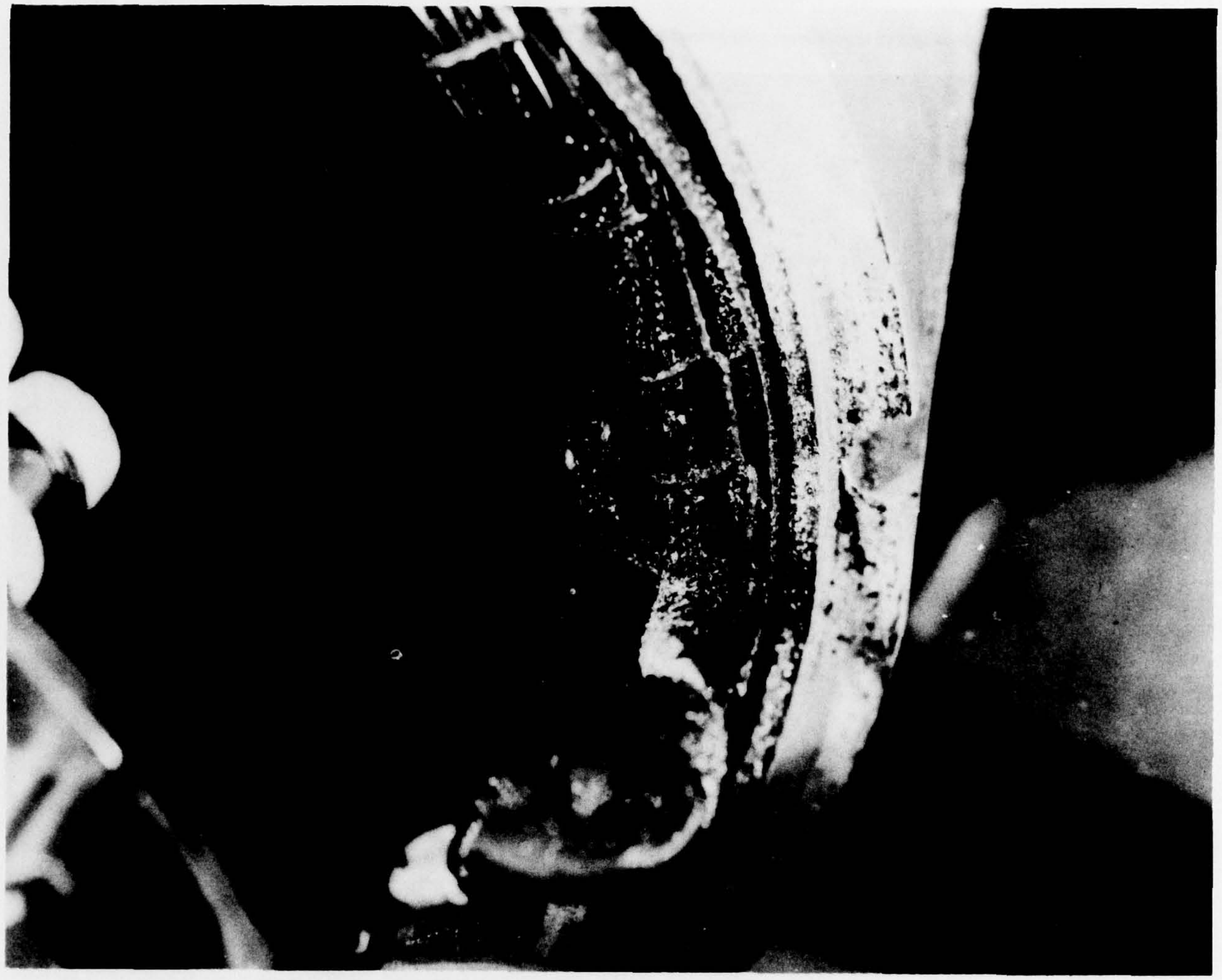


Figure 6.3. Motor damage to field winding caused by disintegration of soft solder joints.

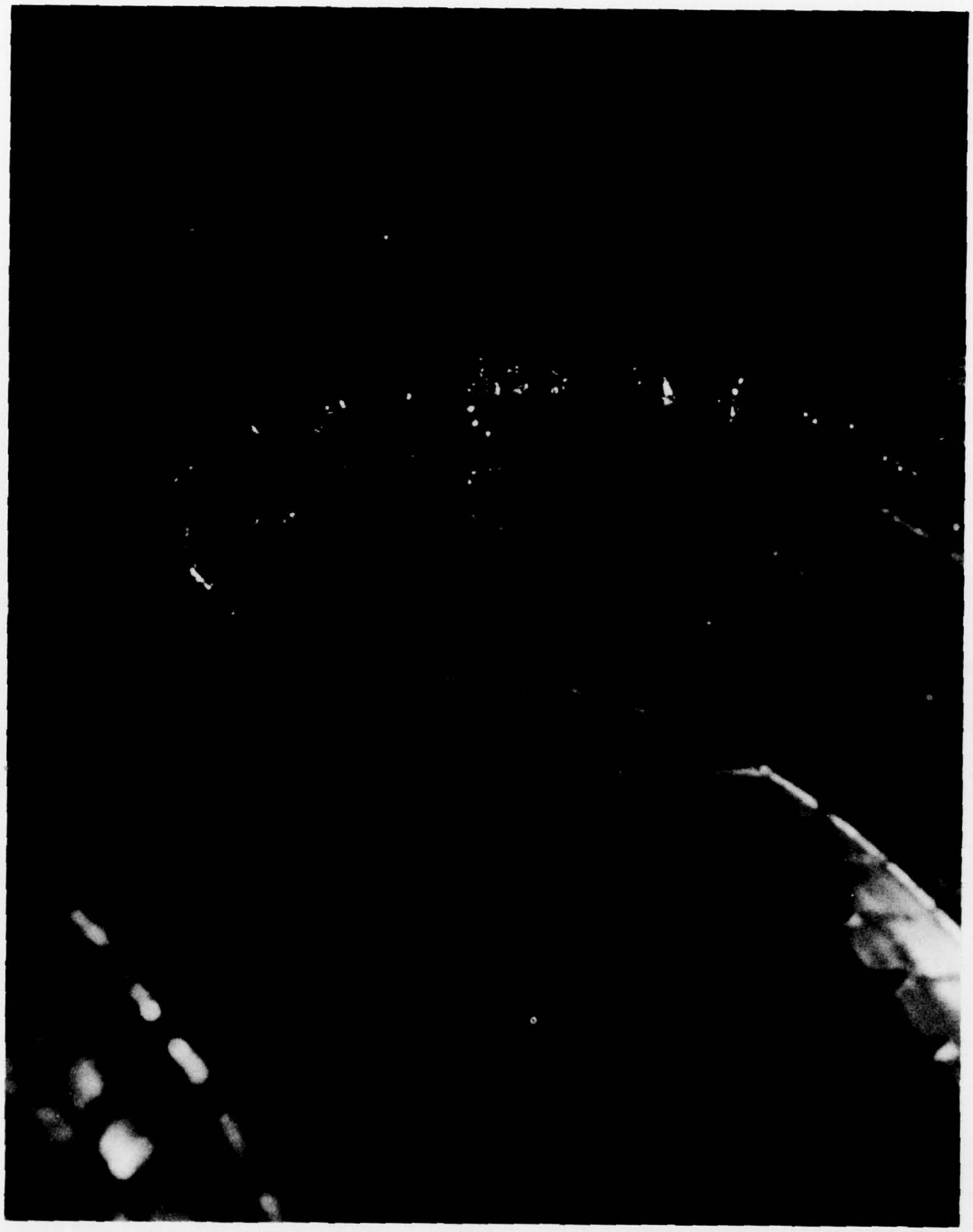


Figure 6.4. Motor damage to commutator risers caused by disintegration of soft solder joints.

Figure 6.5. Motor damage to brush housing caused by disintegration of soft solder joints.

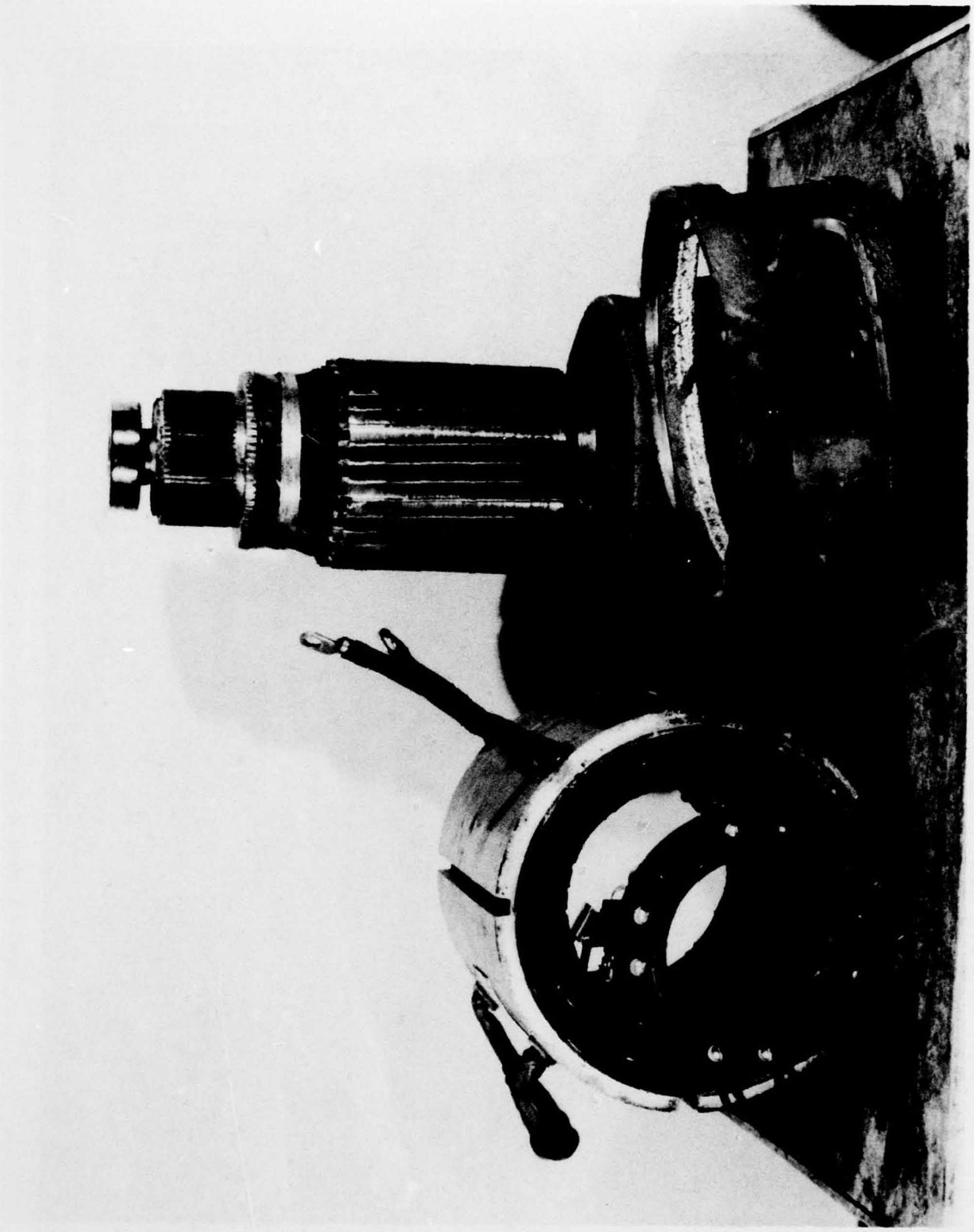


Figure 6.6. Overall view of motor damage caused by disintegration of soft solder joints.

VII. THEORY OF OPERATION

A. ANALYSIS OF PROPULSION SYSTEM PERFORMANCE

1. **General.** Motor speed control in an electric vehicle propulsion system can be attained by a solid state switch whose variable on-off conduction duty cycle transfers a proportional quantity of pulsed energy from the dc power source into the dc motor. As stated elsewhere (Ref. 2) the pulsed battery current is alternately stored and expended within the dc motor, predominantly within its series field, during each period of conduction and succeeding freewheeling operating mode. In this way an energy transfer is maintained from a high voltage, low current dc supply into a high current, lower dc voltage amplitude demanding load. The transformation ratio of the average supply and load current amplitudes is a controlled variable and is commensurate with the conduction duty cycle of the solid state switch. Though seemingly simple, the pulsating current demanded from the source is equal in amplitude to the instantaneous current demanded by the motor combined with the exponentially rising and decaying dc current amplitude in the motor, this operating mode generates power losses in excess of losses normally associated with the dc motor and the battery when operated in the continuous dc power mode.

2. **Pulsomatic Mark 10 Controller.** The simplified schematic for this chopper, shown in Figure 7.1, contains a thyristor switch (TH1) which is triggered at the gate at a repetition rate of ω_c, and force commutated by an external commutating circuit. At the instance of gate triggering TH1, precharged commutation capacitor (C4) discharges through TH1 and diode (D4), such that the positive charge at its upper terminal is tranferred to the lower terminal. Charge reversal accomplished, it is then possible to commutate thyristor (TH1) either by gate or anode triggering of thyristor (TH2). Capacitor (C4) discharges again, in the process displacing the forward current in TH1 with a larger current amplitude in the reverse direction, yielding the commutation of TH1. As the lower terminal of C4 continues to be depleted, its upper terminal is recharged by the now decreasing motor current amplitude until its terminal voltage exceeds the battery supply voltage (EBAT). At this point the upper terminal of C4 is clamped to EBAT by the inverse by-pass diode (D2), and excess charge is circulated through the battery and thyristor (TH2) in its reverse direction until this device is commutated. The stored energy in the motor continues to be expended, meanwhile, locally through freewheeling diode (D2) until TH1 is retriggered.

It is noteworthy that the elapsed minimum conduction period of thyristor (TH1) prior to its earliest possible commutation is relatively constant at ($T \simeq \pi \cdot L \cdot C4$), is independent of load and current amplitude variations*, and solely a function of resonant recharge interaction between capacitor (C4) and inductor (L). Control of power transfer from the source to the motor through manipulation of the conduction duty cycle of TH1, hence, is primarily accomplished by a variable gate trigger control frequency (fc) between typically zero and 400 Hertz, and only to a lesser degree through variation of the conduction period in this application.

3. **Impact of Chopper Current on Motor Performance.** A general analysis of motor performance in the continuous dc current mode versus the pulsating dc current mode, and its impact on battery performance, is necessary for the understanding of the requirements for instrumentation.

In the continuous dc power operating mode, motor power (PAMOT) for a specific level of power (PTR) delivered at the shaft is (7.1):

* The initial current amplitude is relatively constant @ IC4 = 330A peak.

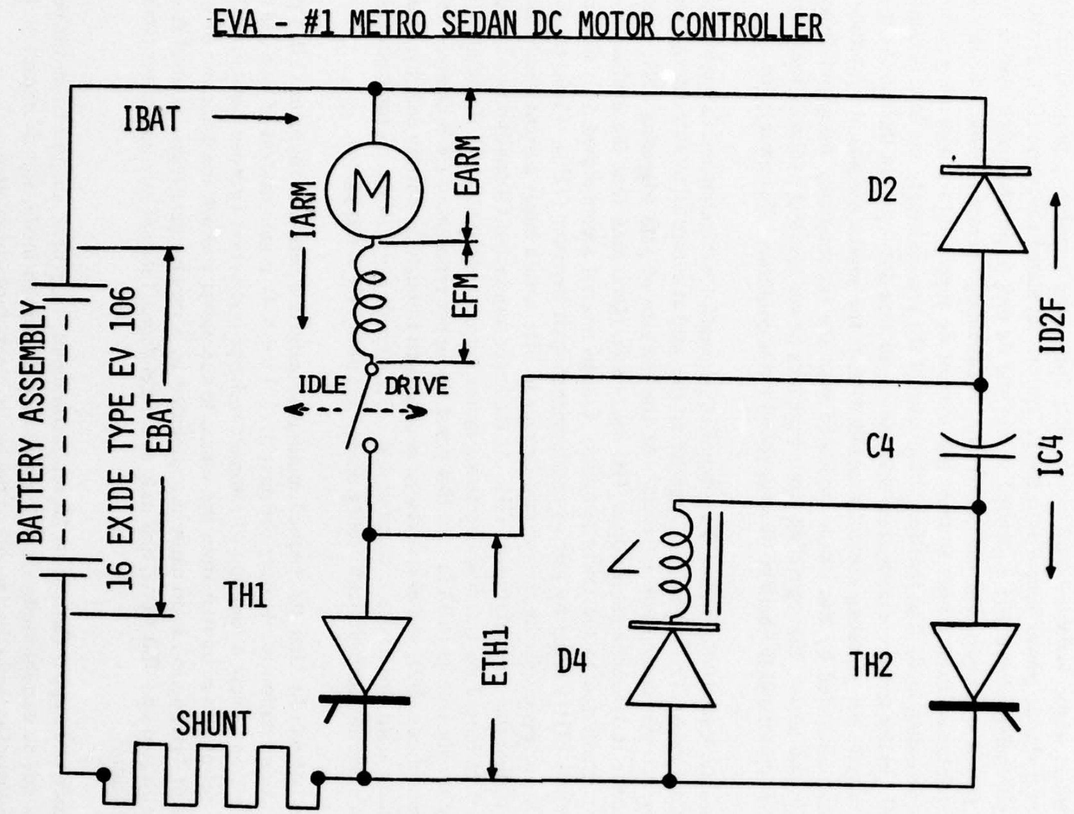


Figure 7.1. Simplified circuit schematic for CABLEFORM pulsomatic mark 10 controller.

(7.1) $$PAMOT = I^2 ARM \cdot R_o \qquad [WDC]$$

whereby

IARM = Armature current, ADC
R_o = $R_F + R_A + R_L$, ohm
R_F = Field resistance, ohm
R_A = Armature resistance, ohm
R_L = Apparent load resistance, ohm

Correspondingly, the efficiency (ηAMOT) IS (7.2.):

(7.2) $$\eta AMOT = (PTR/PAMOT) \cdot 100 \qquad [\%]$$

As a recipient of pulsating dc power from the dc chopper shown in Figure 7.1, the motor will incur additional power losses due to current harmonics. The increased current amplitude (IMOT), derived from Reference (2), for steady state load conditions is (7.3):

(7.3) $$IMOT = \frac{EBAT}{R_o \pi} \left[\left(\frac{\theta_1 \omega_c}{2} \right)^2 + \frac{4}{1 + (\omega_c T_o)^2} \sum_{n=1}^{n=\infty} \frac{1}{n^2} \cdot 2 \sin^2 \frac{n \theta_1 \omega_c}{2} \cdot \cos^2 n\omega_c \left(t - \frac{\theta_1}{2} \right) \right]^{1/2}, \qquad [ARMS]$$

whereby

EBAT = Supply voltage to dc chopper, VDC
θ_1 = Chopper conduction period, s
π = Radians per cycle
ω_c = $2\pi f_c$ = chopper control frequency, rad/s
n = Harmonic coefficient
T_o = L_o/R_o, s
L_o = Circuit inductance = $L_F + L_A + L_L$, H
L_F = Inductance of series field, H
L_A = Armature inductance, H
L_L = Apparent load inductance, H

and

$$IARM = (EBAT \cdot \theta 1 \cdot \omega_c)/(2\pi R_o) \qquad (ADC)$$

Correspondingly, motor power requirement (PMOT) and efficiency (ηMOT) for this pulsating current mode is (7.4) and (7.5) respectively:

(7.4) $$PMOT = I^2 MOT \cdot R_o \qquad (W)$$

(7.5) $$\eta MOT = (PTR/PMOT) \cdot 100 \qquad (\%)$$

Inasmuch as motor performance is usually established for the continuous dc power mode, its actual operating efficiency (ηMOT) for the pulsating dc power mode can be predicted by (7.6):

$$\text{(7.6)} \qquad \eta\text{MOT} = \eta\text{AMOT} \cdot (\text{IARM}/\text{IMOT})^2 \qquad (\%)$$

The relative degradation of motor performance (DEGM) when receiving pulsating dc power is (7.7):

$$\text{(7.7)} \qquad \text{DEGM} = [(\eta\text{AMOT} - \eta\text{MOT})/\eta\text{AMOT}] \cdot 100 \qquad (\%)$$

Inspection of equation (7.7) reveals that degradation of motor performance is directly related to the magnitude of its ripple current. The product (ω_c T_o) within the boundaries $10 \geqslant \omega_c\ T_o \geqslant 1$ maintains the magnitude of motor degradation usually at a low level. Its upper limit is based on the acceptable change of motor resistance (R_F) and (R_A), and as such the increase of motor losses, due to higher order current harmonics.

Battery performance is also impacted by the requirement to furnish pulsating dc power to the dc chopper load. Its peak current demand rises with decreasing dc chopper conduction duty cycle (Δ MOT) when supplying continuous dc power at a constant average magnitude. Correspondingly, the power loss (PLBAT) in the battery for the pulsating dc power mode increases in magnitude beyond its power loss (PLABT) in the continuous dc power mode, and is described in equations (7.8) and (7.9):

$$\text{(7.8)} \qquad \text{PLBAT} = (\text{IBAT}_{(\text{RMS})}/\text{IBAT}_{(\text{AVG})})^2\,\text{PLABT} \qquad (\text{W})$$

The entire power demand (PEV) for the electric propulsion system without the automatic transmission, as derived from Section X, increases to (7.9):

$$\text{(7.9)} \qquad \text{PEV} = \text{PABAT}/(\Delta\text{MOT})^{a5} + (\text{IBAT}_{(\text{RMS})}/\text{IBAT}_{(\text{AVG})^2}\ \text{PLABT}$$

Degradation of power transfer (DEGM) in the pulsating dc power mode is therefore (7.10):

$$\text{(7.10)} \qquad \text{DEGEV} = (\eta\text{AEV} - \eta\text{EV})/\eta\text{AEV}) \cdot 100 \qquad (\%)$$

It is noteworthy that the circuit inductance (L_o) as well as the inductance of the series field (L_{FM}) are measurable directly as real values with a programmable instrumentation package used by MERADCOM, and as described in Section X, and are relatable to motor flux level. At this point circuit inductance (L_o), as defined in Reference (2) by its energy requirements of the motor to sustain continuous dc current flow (IARM) during the free wheeling period, is (7.11):

$$\text{(7.11)} \qquad L_o \geqslant 2\left[\left(\frac{2\pi}{\omega_c} - \theta 1\right)(\text{EBAT} - \text{EMOT})_{[\text{AVG}]}\right]/\delta\ \text{IARM} \qquad (\text{H})$$

whereby,

EMOT = Motor Voltage

L_L = $[1.78 \cdot \text{NTR}\,\Delta\,\text{NTR}/60 \cdot g]\ \sum_{\forall}\ \overline{\text{WR}}^2 \cdot \theta 1$

NTR = Motor shaft speed, r/min.
ΔNTR = Incremental speed change, r/s^2
δIARM = $|IARM|_{MAX} - |IARM|_{MIN}$, Apk
$\Sigma(\overline{WR}^2/g)$ = sum of all inertia, e.g.; rotor, gearing wheel or dynamometer; g = 9.81 m/s^2 (mkg)

The in-circuit field inductance (LFM) can be obtained by indirect measurement and from equation (7.12) whereby circuit inductance (LFM) is calculated at various incremental current amplitudes (IARM) for which the ripple current (δIARM) and the forward voltage step function across the series field (EFM (FWD)) can be measured during each conduction interval of thyristor (TH1).

(7.12) $$LFM = EFM(FWD) \cdot \delta t/\delta IARM$$

B. MONITORING BATTERY ENERGY TRANSFER EFFICIENCY

1. **Conventional Method.** Prior to evaluation of energy transfer efficiency, the battery is usually made to undergo various discharge and charge cycles in an attempt to equalize the charge level between individual cells. During the final preparation, prior to taking data, the battery undergoes typically three deep discharge and recharge cycles, whereby during the first and third cycle the battery is discharged at the six hour discharge current (IBAT1) rate; and during the second cycle at two times this current rate. At this point the battery has been "soaked" well enough to sustain manufacturer's specified battery capacity.

The initial open circuit terminal voltage/cell of the fully charged battery is 2.1 V at a battery temperature of typically 15.5°C. Maintaining the aforementioned constant discharge rate (IBAT1), at a 100% depth of discharge the battery voltage has diminished to 1.75 V. Inasmuch as the cell voltage decreases rather evenly with the depth of discharge, shown in Figure 7.2, the average cell voltage over the entire discharge cycle (EBAT1) is approximately 1.895 V AVG. Correspondingly, the average energy (TBAT1) is (7.13):

(7.13) $$TBAT1 = 1.895\,(V) \cdot IBAT1\,(A) \cdot tl(s) \qquad (J)$$

Charging of the battery is based on a floating voltage battery charger, its voltage limited to a 2.36 V maximum/cell. Constant charge/discharge current amplitudes are considered equal in magnitude. For the completely discharge battery the instantaneous cell voltage increases during charge from a floating voltage $EBAT_{min} \simeq 2.18V$ $EBAT_{max} = 2.36$ volt. Then the current (IBAT2) tapers off slowly toward zero. It is common practice that the total Ampere-hours expended during charge equal 1.2 times the ampere-hours expended during discharge. Thus, referring to the single cell voltages of Figure 7.2, the average cell voltage for the charge cycle is EBAT2 = 2.293 V AVG. Approximate energy (PBAT2) to charge the battery (7.14):

(7.14) $$PBAT2 = 2.293(V) \cdot 1.2IBAT(A) \cdot tl(s) \qquad (J)$$

Accordingly, the typical lead acid battery energy transfer efficiency (EFFBAT) is (7.15):

(7.15) $$\eta BAT = 1.895/(1.2 \cdot 2.293) \times 100 = 68.9 \qquad (\%)$$

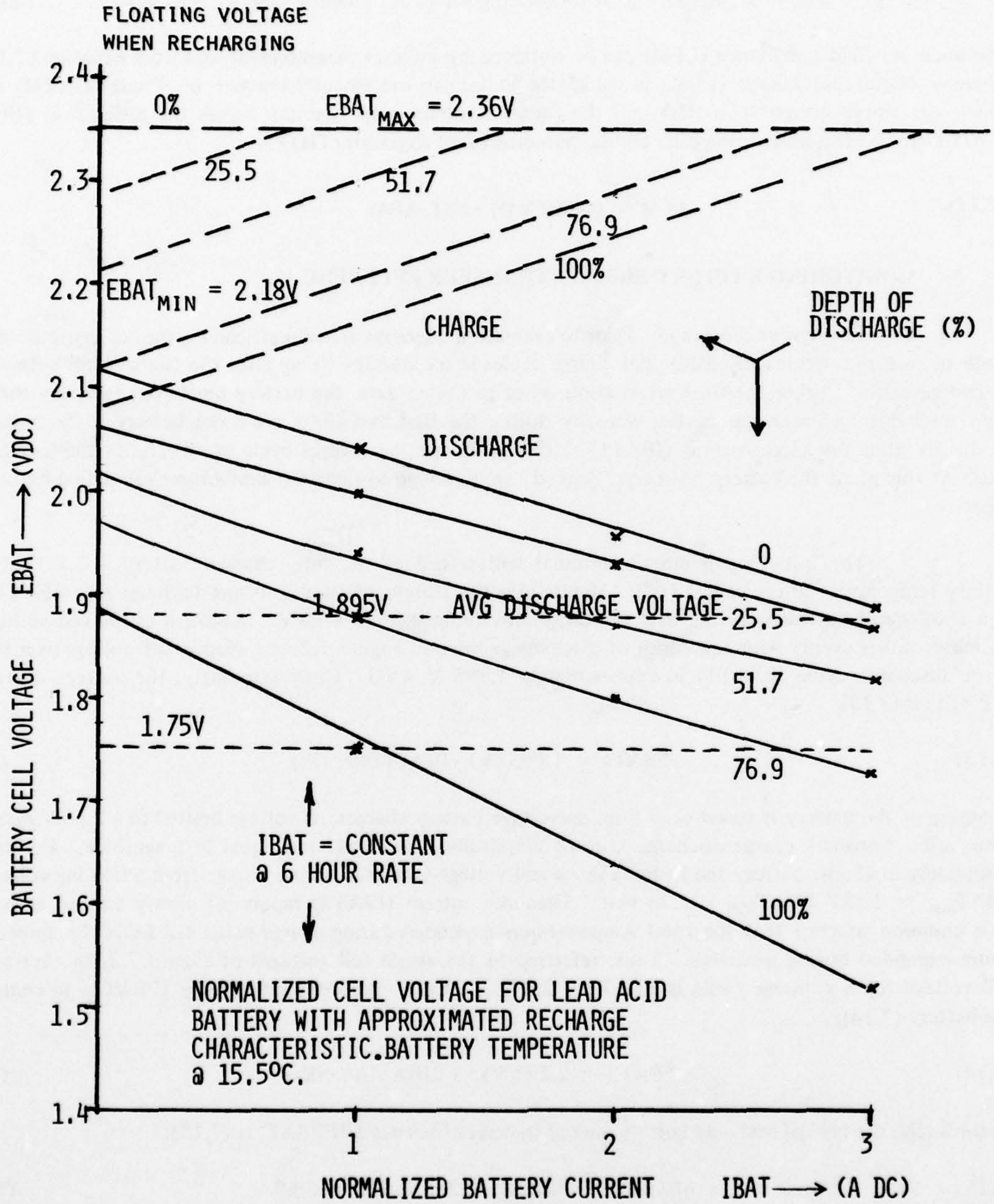


Figure 7.2. Battery cell voltage vs. charge level.

In practice battery voltage is determinable only by a monitor because it is dependent on battery condition other than the charge level, e.g.: electrolyte, sulphation of electrodes, short- or open circuiting of plates, but most importantly, battery temperature. According to J. Mas (Ref. 3) cell voltage is required to rise as high as 2.6 V @ minus 18°C temperature to achieve a full charge capability, and as low as 2.1 V @ 60°C. This is shown in Figure 7.3. Thus, at low temperature, the required average cell voltage accordingly decreases during an entire charge cycle increases to 2.59 V AVG, and battery energy transfer efficiency accordingly decreases to 61%.

A rise of battery (electrolyte) temperature must be accomplished with a corresponing reduction of cell voltage to prevent uncontrolled gasing, and potentially subsequent overheating of the plates or grids accompanied by loosening of active material. This in turn requires constant monitoring of the battery charge condition. Control of the quality of battery charge operation with the aid of a hydrometer or cadmium tester appears to be somewhat arbitrary because the monitoring of specific level of gravity cannot determine the density of the electrolyte in the pores of the plates or grids, and because of stratification at the bottom of the container. The many uncontrolled variables seem to frustrate the establishment of a repeatable performance criteria for energy transfer performance in this type of battery.

2. **Improved Method.** In an attempt to reduce ambiguities when monitoring the rate of charge in the battery, a gas pressure monitor was utilized in the center cell of a three-cell pressure tight battery assembly to control the current amplitude of the battery charger. Upon demand, the average value of current was automatically reduced in magnitude such that the gas pressure did not exceed 1.3 cm (0.5 inches) of water through a specified orifice. The discharge cycle was limited to the point of voltage inflection, e.g.: rapid deterioration of either cell voltage to typically $2.1V/\sqrt{2} \rightarrow 1.48VDC$ @ IBAT = Constant, or preferably of available output power $PABAT \geqslant PABAT_o/\sqrt{2}$.* The charge cycle was limited to the point of inflection of the charge current, e.g.: rapid decrease of current amplitude (IBAT2) to limit gasing. This is shown schematically in Figure 7.4.

Having optimized the point-of-inflection on the power discharge curve, at a given discharge-current rate (IBAT1), the WATT-HOUR and AMPERE-HOUR values must be monitored at this point. Very often these values have to be extrapolated from a strip chart from known values at points adjacent to, and spanning this point-of-inflection. Thus, the WATT-HOUR EFFICIENCY (ηBAT1) will be based on the knowledge of the AMPERE-HOURS of DISCHARGE at the point-of-inflection, followed by a search of the charge curve to locate that value of AMPERE-HOURS and the corresponding WATT-HOURS. The WATT-HOURS correspond to the same AMPERE-HOURS on CHARGE as on DISCHARGE. The efficiency (ηBAT1) accordingly is (7.16):

$$\eta\text{BAT1} = (\text{WATT-HOUR DISCHARGE}) / (\text{WATT-HOUR CHARGE}) \cdot 100 \quad (\%) \tag{7.16}$$

The AMPERE-HOUR EFFICIENCY (ηBAT2) will be based on the knowledge of the WATT-HOURS of DISCHARGE at the point-of-inflection, followed by a search of the CHARGE curve to locate that value of WATT-HOURS and the corresponding AMPERE-HOURS. Thus AMPERE-HOURS correspond to the same WATT-HOURS on CHARGE as on DISCHARGE; and the efficiency (ηBAT2) is the reciprocal of these data and is (7.17):

$$\eta\text{BAT2} = (\text{AMPERE-HOURS CHARGE}) / (\text{AMPERE-HOURS DISCHARGE}) \cdot 100 \quad (\%) \tag{7.17}$$

* Subscript "o" denotes available power from fully charged battery into constant resistor load.

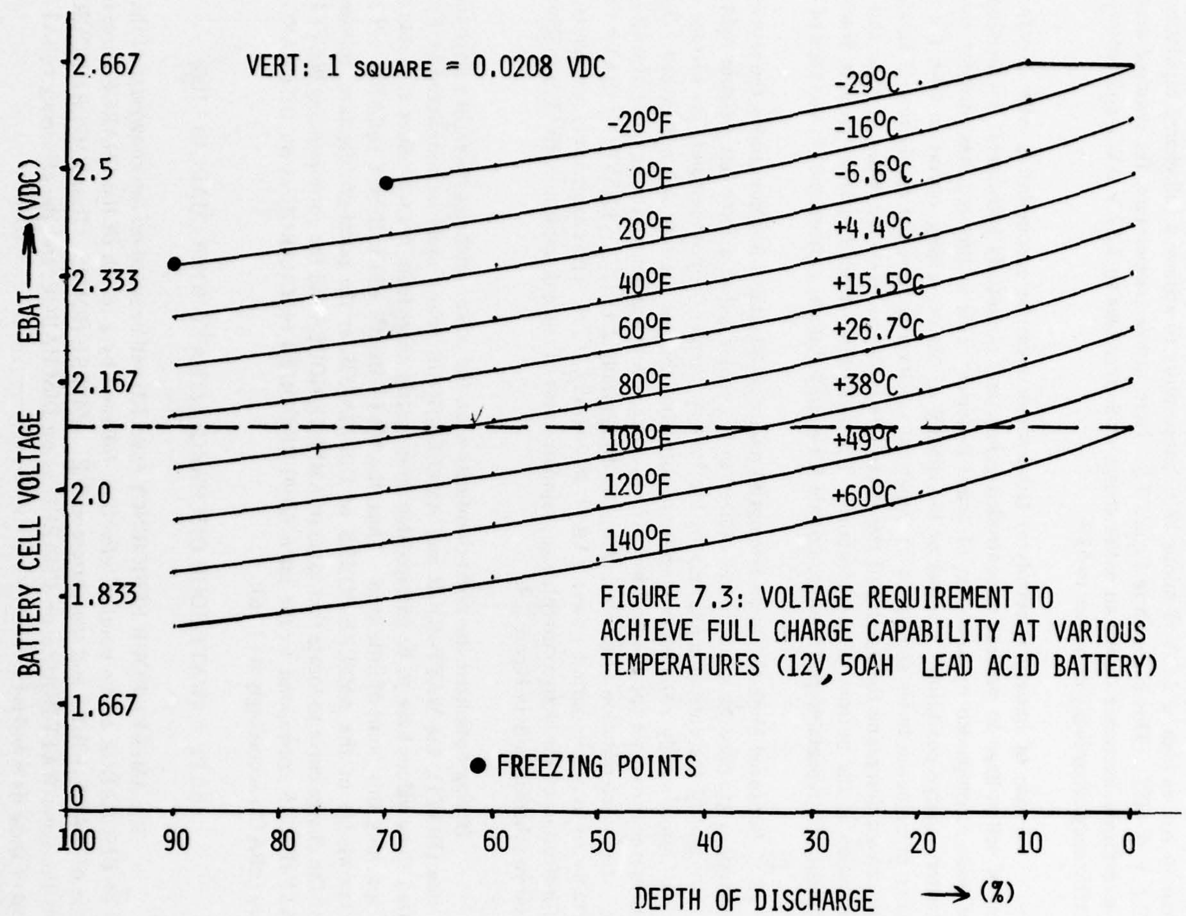


FIGURE 7.3: VOLTAGE REQUIREMENT TO ACHIEVE FULL CHARGE CAPABILITY AT VARIOUS TEMPERATURES (12V, 50AH LEAD ACID BATTERY)

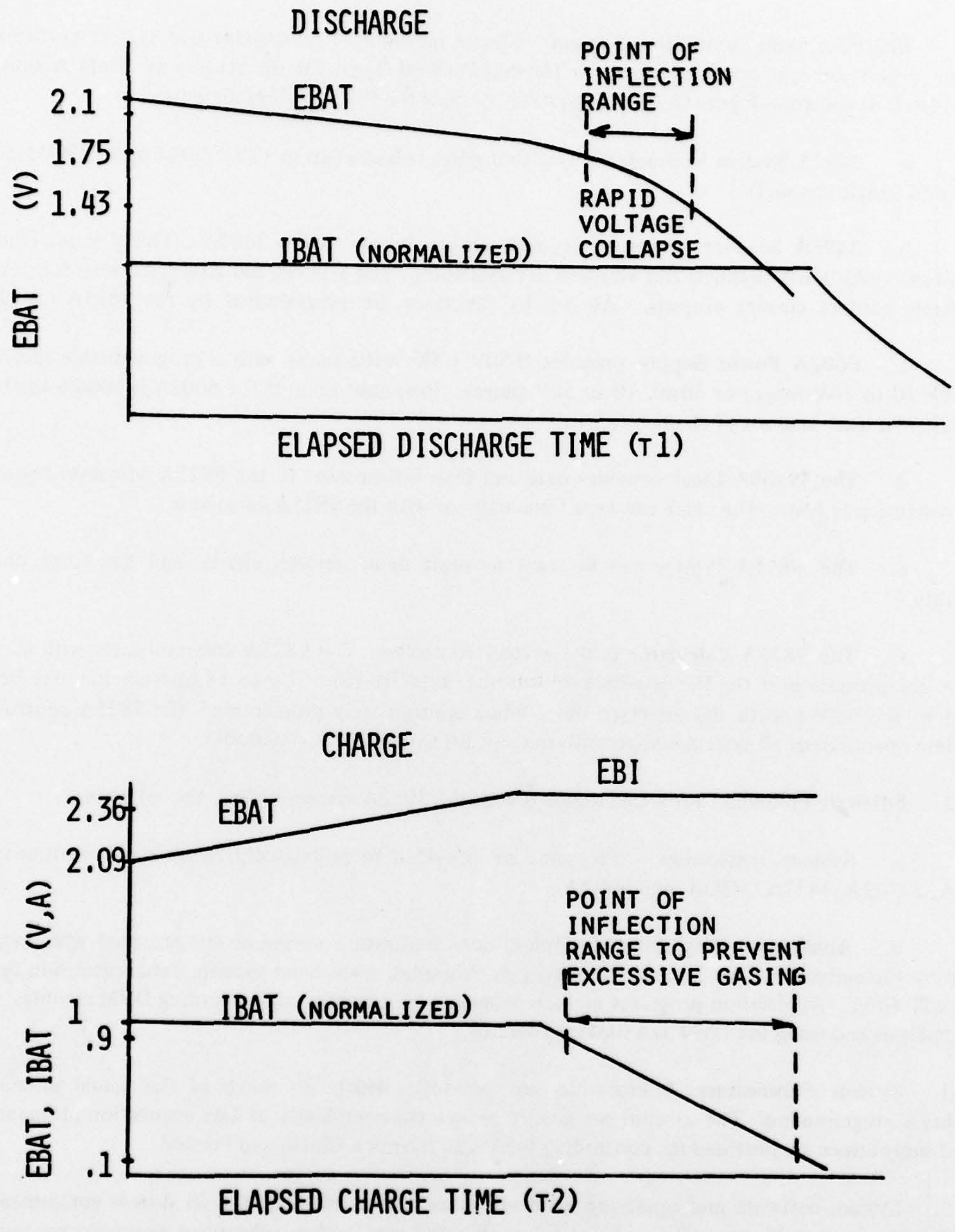


Figure 7.4. Point of inflection for discharge and recharge cycles.

VIII. DATA ACQUISITION

1. **HP3052A Data Acquisition System.** Electro-mechanical component and system performance test and evaluation was conducted with a Hewlett-Packard Type 3052A Automatic Data Acquisition System (Ref. 4) shown in Figure (8.1). The system contains the following instruments:

a. **3437A System Voltmeter** is used to digitize voltages (up to ±20V dc) at up to 4900 readings per second (single channel).

b. **3495A Scanner** is used to connect various inputs to the 3437A. Thirty input channels are utilized (additional channels and scanners are available). The scanner has also provisions for ten programmable contact closure outputs. All 3495A functions are programmed by the 9825A calculator.

c. **6002A Power Supply** provides 0-50V (200 watts max) with a programmable resolution of 10mV (0 to 10V range) or 60mV (0 to 50V range). Response time of the 6002A is 100mS to 400mS depending on load, amount of change, etc.

d. **The 59309A Clock** provides date and time information to the 9825A whenever requested. Time resolution is 1 sec. The clock can be set manually or with the 9825A calculator.

e. **The 9871A Printer** can be used to print data, reports, charts, and has some plotting capability.

f. **The 9825A Calculator** is the system controller. The 9825A communicates with all other system components over the Hewlett-Packard Interface Bus (HP-IB). Up to 14 instruments may be connected to the 9825A with the interface bus. When appropriately programmed, the 9825A controls the complete operation of all system components (except for some 3968A functions).

2. **Software Programs.** Programs supplied with the 3052A system include the following:

a. **System verification** – Programs are provided to individually check the operation of the 9871A, 59309A, 3437A, 3495A, and 6002A.

b. **Application Programs** – Complete data acquisition programs are provided which may be useful by themselves, but are intended primarily as examples, since most specific data acquisition applications will differ. Application programs include programs for scanning and recording DVM readings, waveform analysis and using the DVM as a timing generator.

3. **System Subroutines.** Subroutines are provided which do much of the actual instrument/peripheral programming. The subroutines greatly reduce the complexity of data acquisition programming. Useful subroutines are provided for controlling the DVM, Scanner, Clock, and Printer.

System software and operating instructions as well as manuals for all system components are provided in a system library. The verification, application, and system subroutine programs are recorded on magnetic tape cartridges for the 9825A calculator. The tapes and printed listings of the programs are included in the system library.

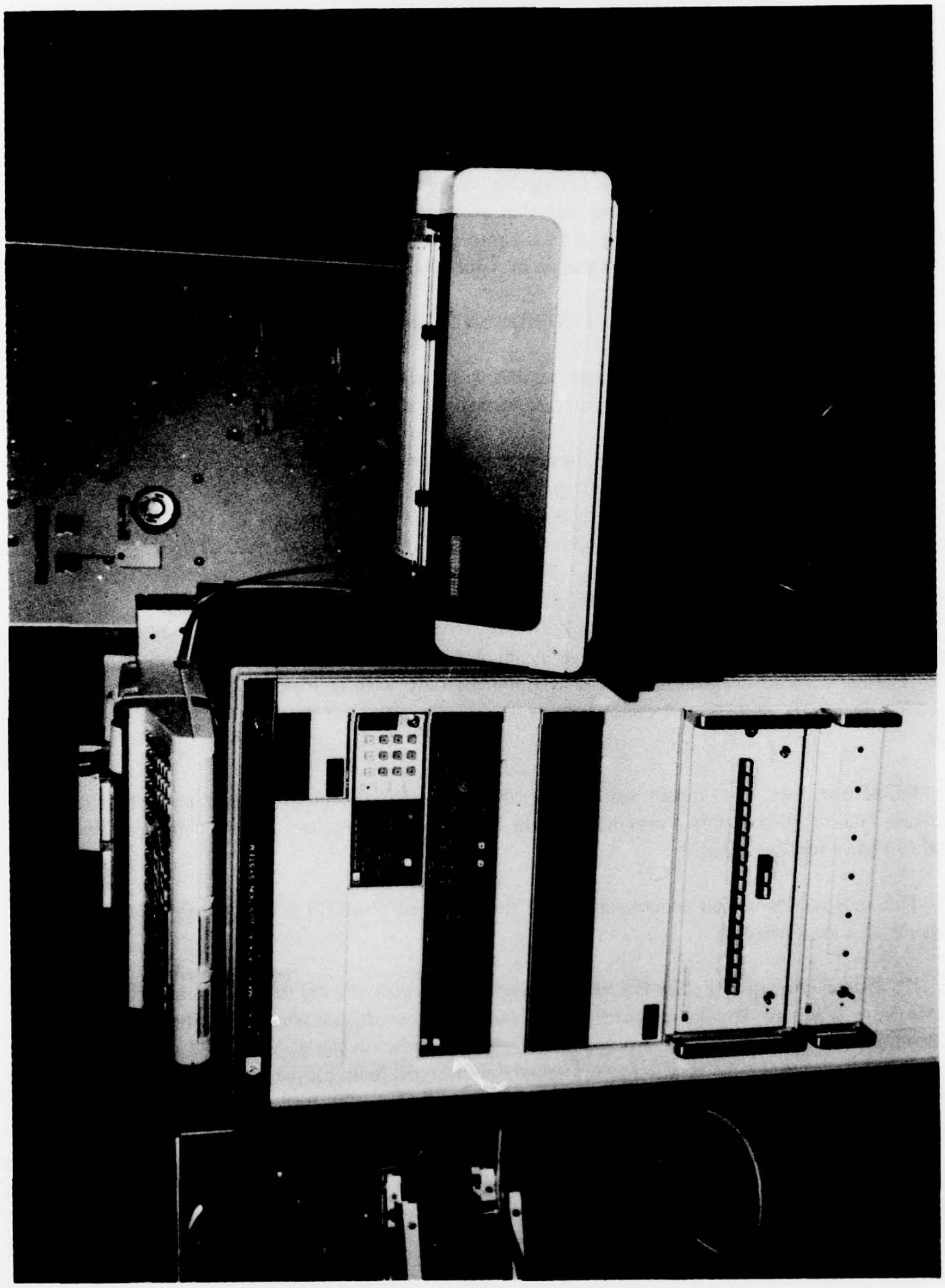


Figure 8.1. HP type 3052A data acquisition system.

Computation of appropriate values of true RMS, true DC or DC with recurrent ripple amplitudes including arbitrary waveforms within a frequency band of 60 to 4000 Hz is attained by a sampling technique which covers all portions of the recurrent waveform over several cycles of operation, and is shown in Figure (8.2).

4. **Data Sampling.** A flow chart and hardware implementation is shown in Figure (8.3). It is assumed that the waveform does not change appreciably over N/X cycles while being sampled (N = number of sample points, X = number of samples per cycle). By establishing a delay in sampling such that the first sample is taken at some arbitrary time and that each successive sample is taken somewhat less than one-half period later, the entire waveform can be sampled in small increments, as shown in Figure (8.4). An application of this sampling technique is shown in Appendix A.

IX. INSTRUMENTATION

The EVA Metro Sedan propulsion system testing was performed by means of a number of individual tests. The individual test designation and instrumentation requirement for these tests are described below.

1. **Transmission Test.** The automatic transmission contains a torque converter, a three speed gear reducer and a drive shaft to the differential gear. The differential gears were replaced with an adaptor, shown in Figure 9.1, to facilitate a single ended output from the transmission. The transmission was tested on the dynamometer #1 test facility, schematically shown in Figure 9.2. Flexible shaft torque transducer, Ametek Type C30 – 500 and C30 – 3000, measured input and output torque, respectively, while motor input was obtained from a three-phase, full wave rectifier bridge and a variac power supply. The test bed for the transmission is shown in Figure 9.3. The torque sensor and its calibration arm are shown in Figure 9.4. Torque sensor's output voltage signal was verified to be within the boundaries of ± ½% of actual reading. Speed measurement was attained digitally with a 30-tooth gear. The transmission was tested under steady state speed conditions vs. output torque, and as function of slip in the torque converter.

2. **DC Motor Test.** DC motor test in the continuous DC power mode was performed on dynamometer test facility #3, as shown schematically in Figure 9.5. Power was obtained from a three phase variac and full wave rectifier circuit.

The motor was tested at constant incremental speed (NMOT) settings, and its torque varied in accordance to a load schedule.

3. **DC Motor Operation in the Pulsating Power Mode.** With the aid of the data acquisition system, data points were taken to determine motor performance and power loss when receiving energy from the 96V dc propulsion battery through the dc controller. Power losses in the dc controller and the propulsion battery were also determined. The constant speed, parametric load torque performance data are converted into constant power/torque variable speed data and presented graphically.

The motor performance test was conducted at the dynamometer #3 test facility, schematically shown in Figure 9.6. Motor speed was measured digitally with a 30-tooth gear wheel. An Ametak torque transducer type C30-500 was used to measure load points between 0-56 N-m. The actual test facility is

HP 3052A DATA ACQUISITION SYSTEM

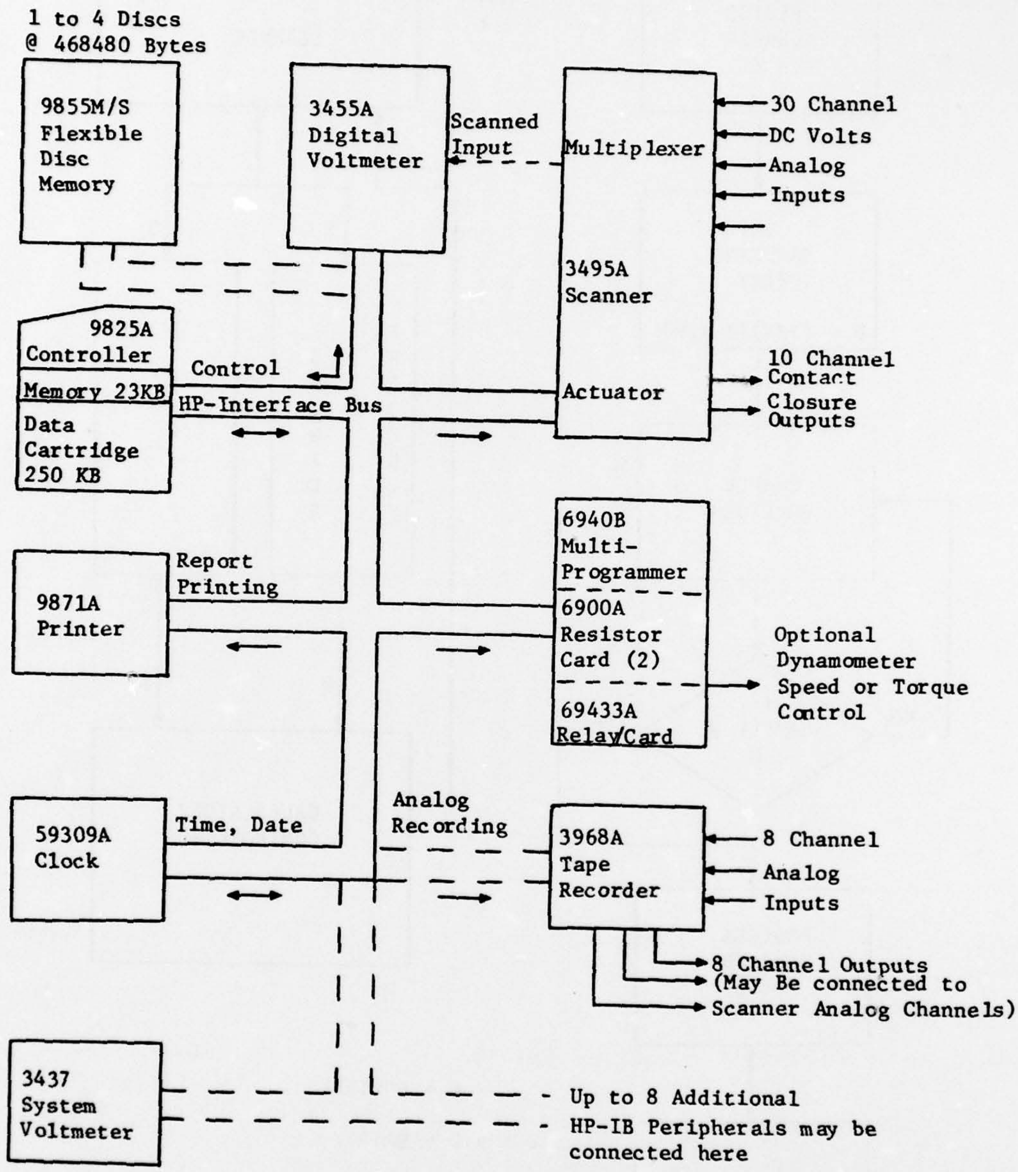


Figure 8.2. Schematic of HP 3052A data acquisition system.

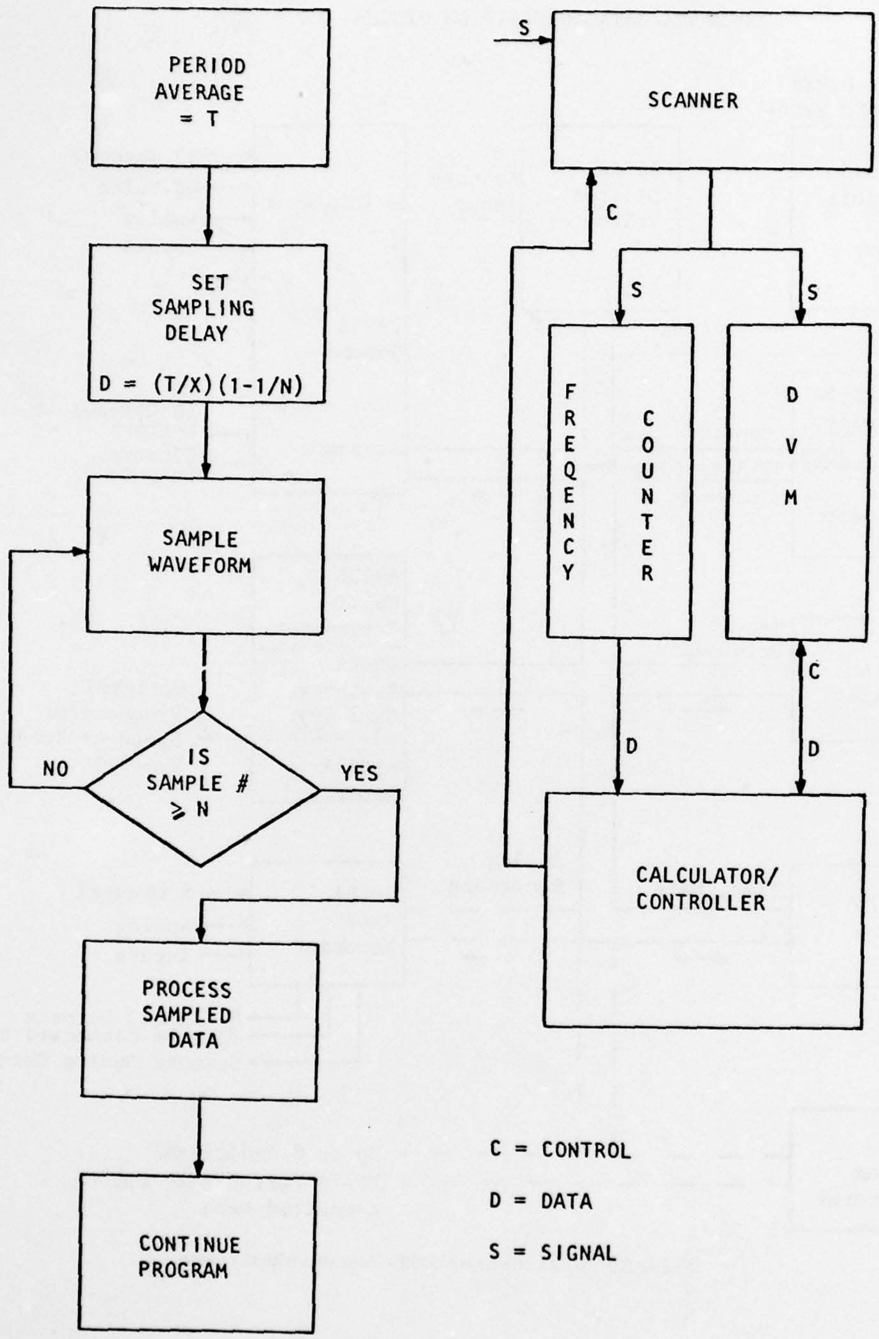


Figure 8.3. Flowchart and hardware implementation of variable frequency, arbitrary waveform voltage measurement.

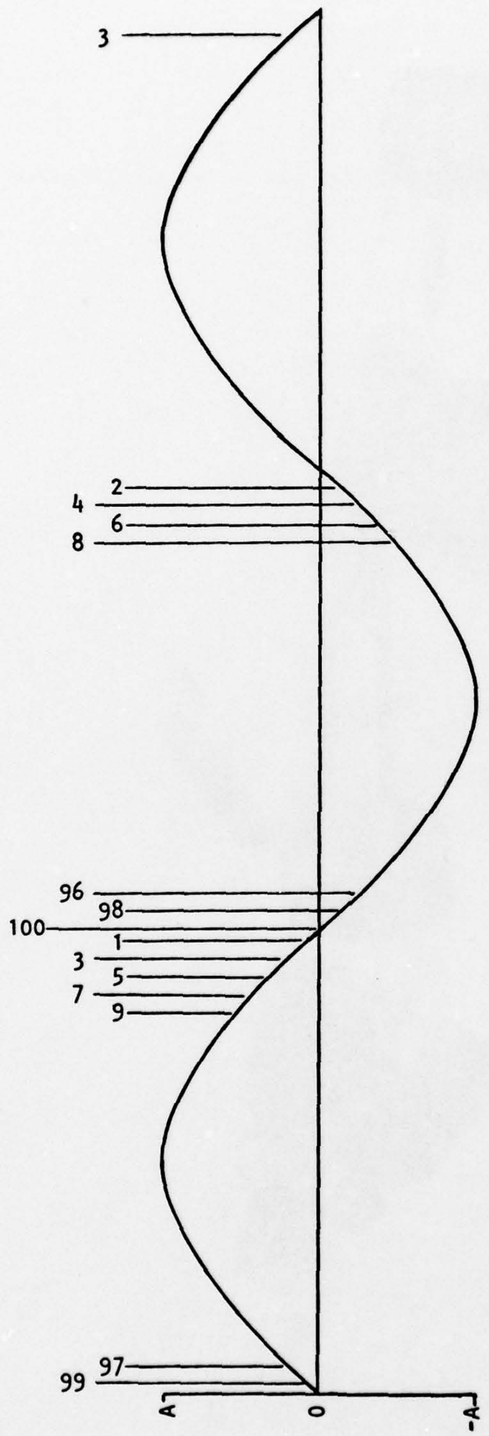


Figure 8.4. Consecutive sample positions for a 100 point sample, waveforms overlaid.

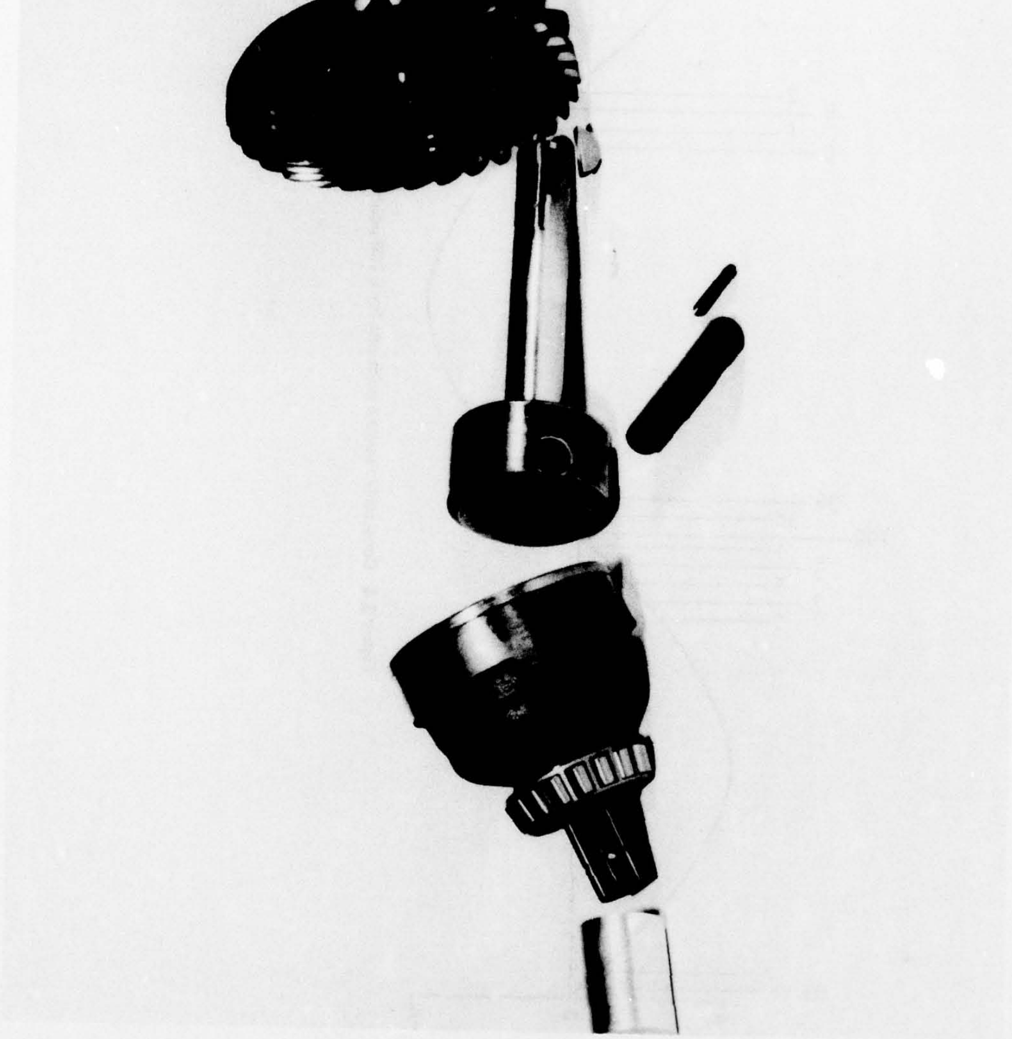
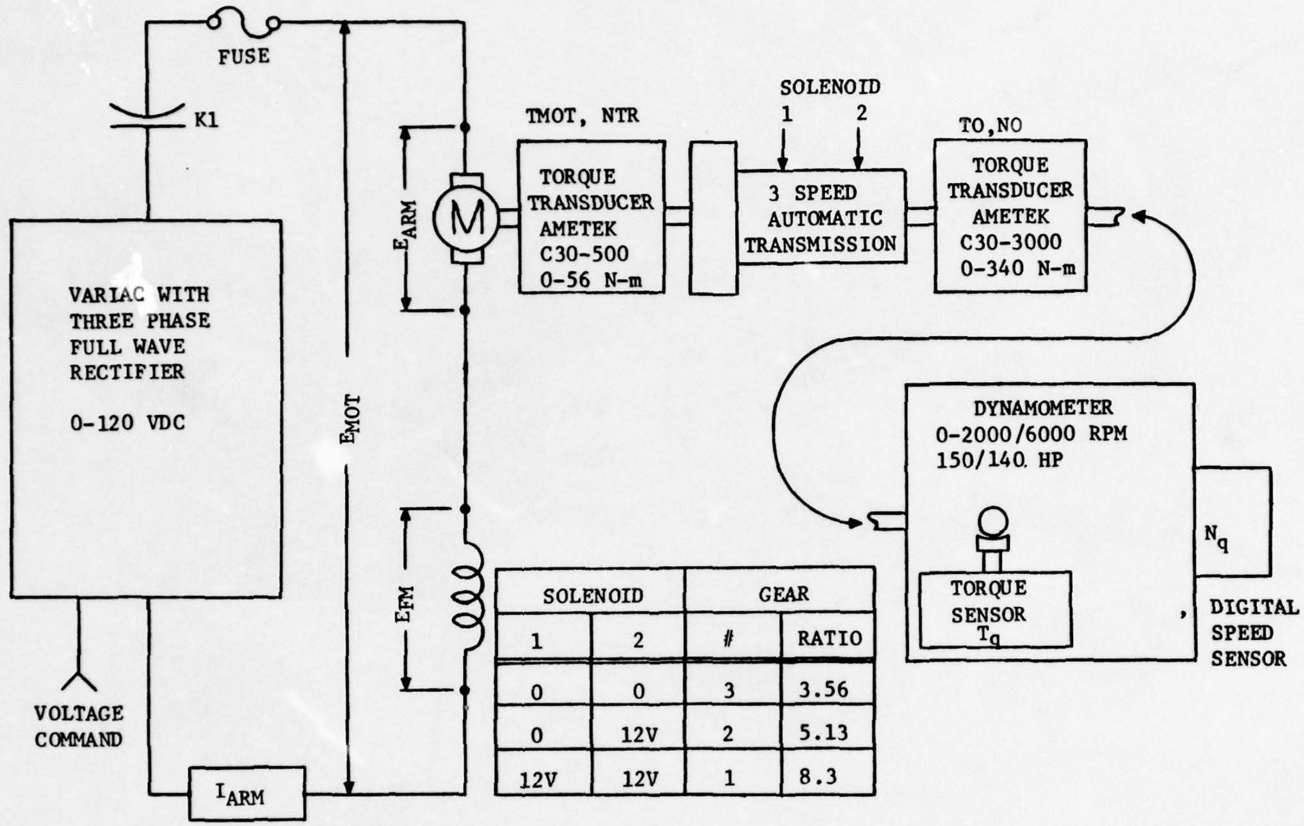


Figure 9.1. Adaptor to lock differential.



SOLENOID		GEAR	
1	2	#	RATIO
0	0	3	3.56
0	12V	2	5.13
12V	12V	1	8.3

Figure 9.2. Schematic of dynamometer No. 1 transmission test facility.

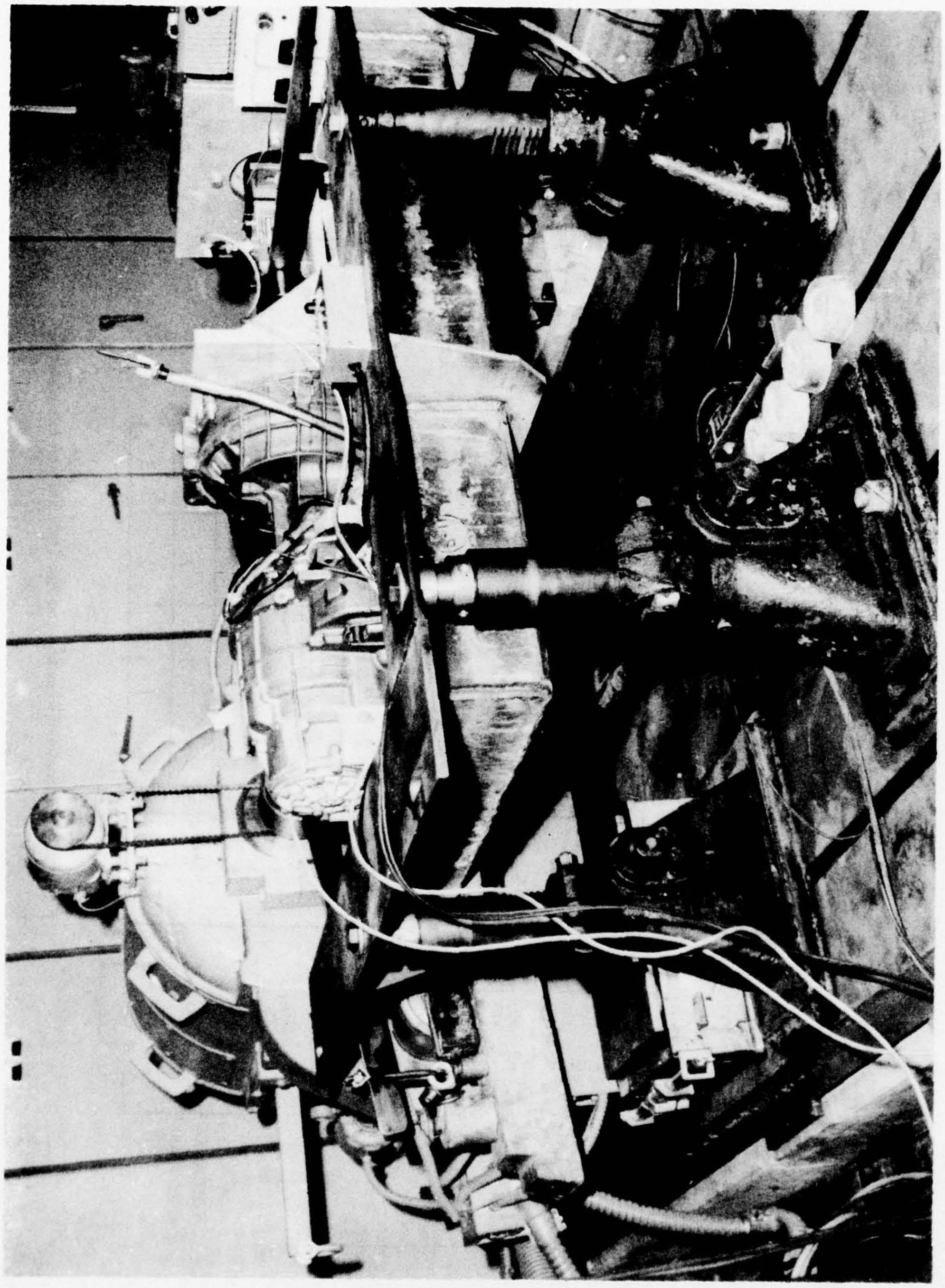


Figure 9.3. Transmission test bed.

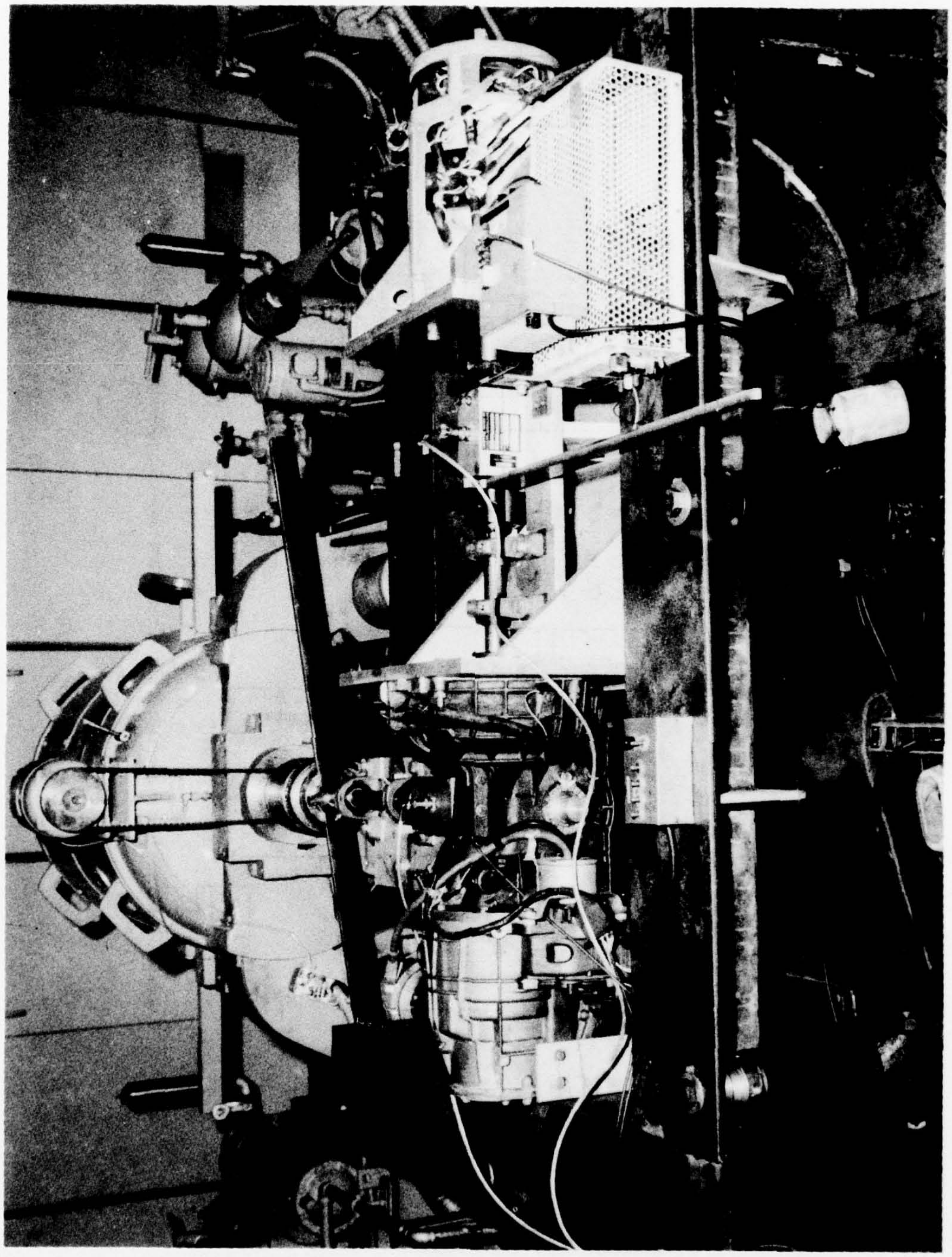


Figure 9.4. Calibration arm for torque sensor.

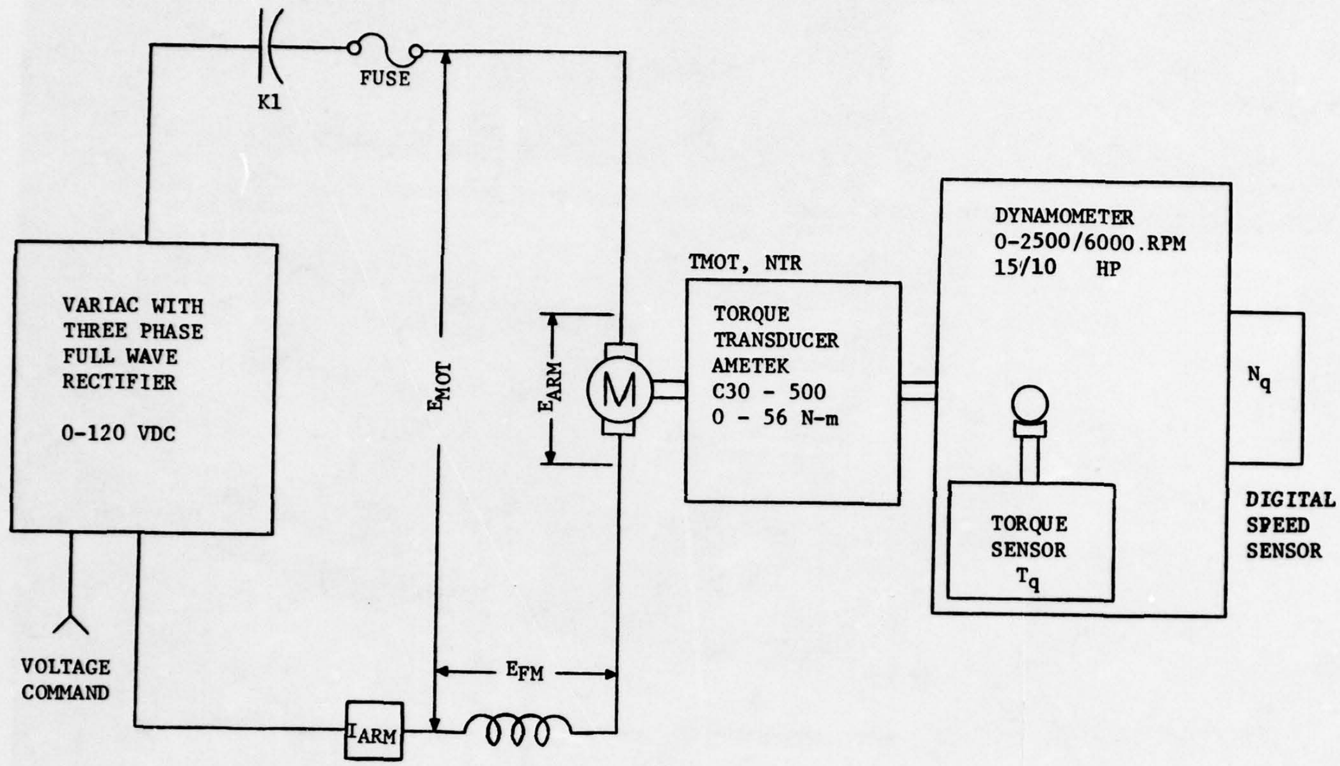


Figure 9.5. Schematic for dynamometer No. 3 DC motor test facility, continuous DC power mode.

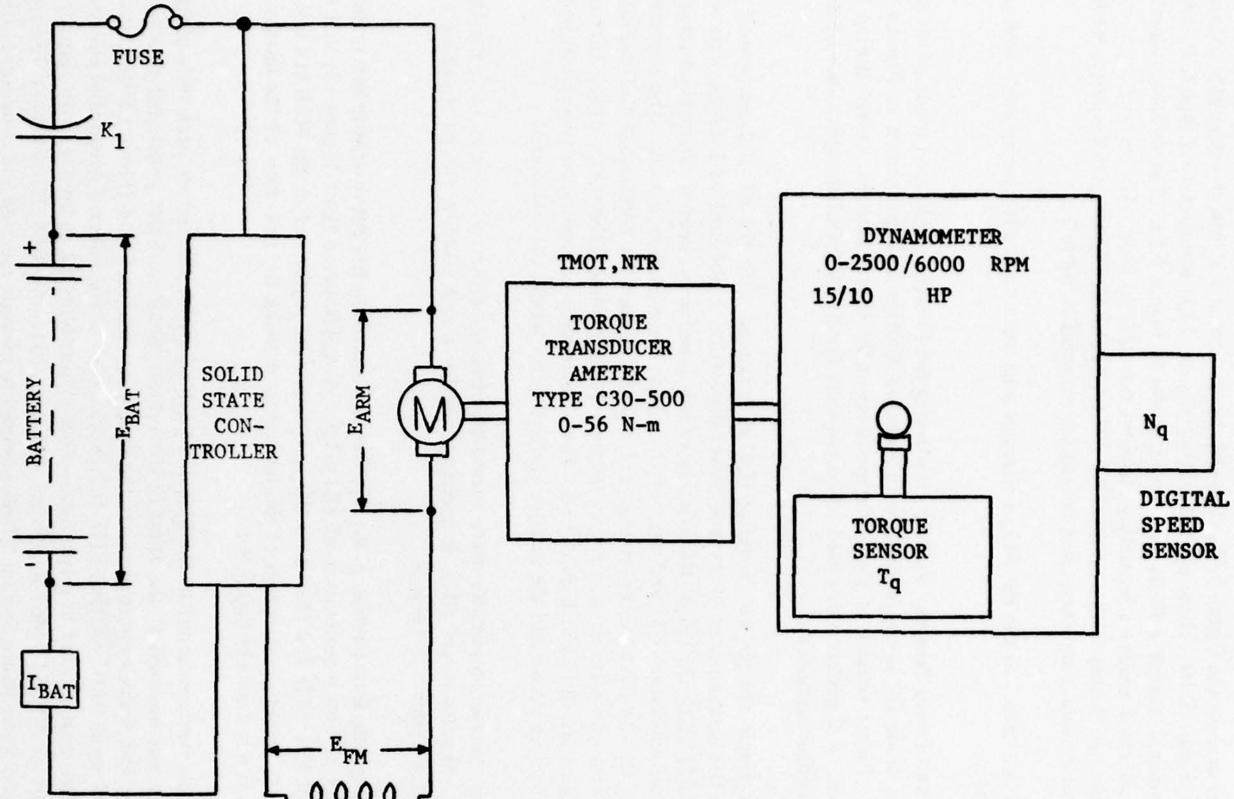


Figure 9.6. Schematic of dynamometer No. 3 DC motor test facility pulsating DC power mode.

shown in Figures 9.7, 9.8, 9.9A and 9.9B. DC chopper controller and battery were placed in direct proximity to the motor to simulate the cable harness in the vehicle, whereby the battery was interconnected in the same manner as shown in Figure 9.9B. The DC chopper panel was instrumented with coaxial current shunts as shown in Figure 9.10. These coaxial current shunts, T&M Research Co., type K-10000-20 were calibrated and compared against a Reference Shunt shown in Figure 9.11. The reference shunt, Weston K 9442-15, was calibrated against a secondary standard traceable to NBS. The coaxial shunt calibration was performed at the test facility with a certified HP 3455A Digital Multimeter, US Property, MERADCOM 1656. Coaxial shunt deviation and correction factors are recorded in Table 2.

All interface cables to the HP 3495A Scanner unit were, typically, terminated with a 15 ohm resistor to reduce noise.

4. **Voltage and Power Sensors.** Voltage drop during the forward conduction mode of thyristor TH1 and inverse bypass diode D2 is conditioned with Forward Voltage Clamps, shown in Figures 9.12 and 9.13 respectively. Either output of these clamps is normally short circuited, except during the "on" period of the device. R-C snubbers are used to compensate for the distributed capacitance of the coaxial cable to the data acquisition system.

The true ripple voltage for capacitor (C4) is measured with the AC Voltage Sensor, shown in Figure 9.14, while the measurement of its true power dissipation is obtained with a solid state wattmeter, shown in Figure 9.15. With the aid of this wattmeter it is possible to measure the true power dissipation within commutation capacitor (C4) and that of the entire commutation circuit. The wattmeter automatically increases the product of the voltage and current vectors for continuous and impulse voltage amplitudes alike with considerable accuracy. Typical RMS reading calibration curves for continuous rectangular waveforms are shown in Figure 9.16. There is virtually no significant phase shift between the relatively constant voltage vector and the variable current vector within the wattmeter.

All other voltage amplitudes were measured directly across the samples with the HP 3455A Digital Multimeter. Manufacturers' (Ref. 4) specifications for the H: 3455A Digital Multimeter, as applicable to this project, are shown in Table 3.

5. **Electromagnetic Interference.** This test was performed on the entire vehicle before disassembly for propulsion tests, to the requirements of MIL-STD 461-A, [Notice 4 (EL), Figure 13] and according to Method RE02 of MIL-STD 462 [Notice 3 (EL)]. Tests were performed in the MERADCOM Shielded Enclosure (EMI Test Facility). A sketch of the test setup showing the plan view of the facility, antenna and vehicle orientation is shown in Figure 9.17.

The vehicle was positioned in the Shielded Enclosure with the battery pack fully charged. The antenna equipment was oriented at the front of the vehicle (hood end) and positioned at one (1) meter test distance. The test scans were made over the frequency range of 0.14 through 1 Ghz. at each load condition as per Method RE02 of MIL-STD 462, Notice 3 (EL) for radiated broadband emissions. The results of these tests were plotted in graph form either manually or by computer in db versus frequency to the requirements of MIL-STD 461-A [Notice 4, Figure 13]. An FSS 250 Fairchild Electro Metrics Computer Controlled Surveillance System S/N69 was used to measure radiated and conducted interference. The instrument's calibration was traceable to National Bureau of Standards (NBS).

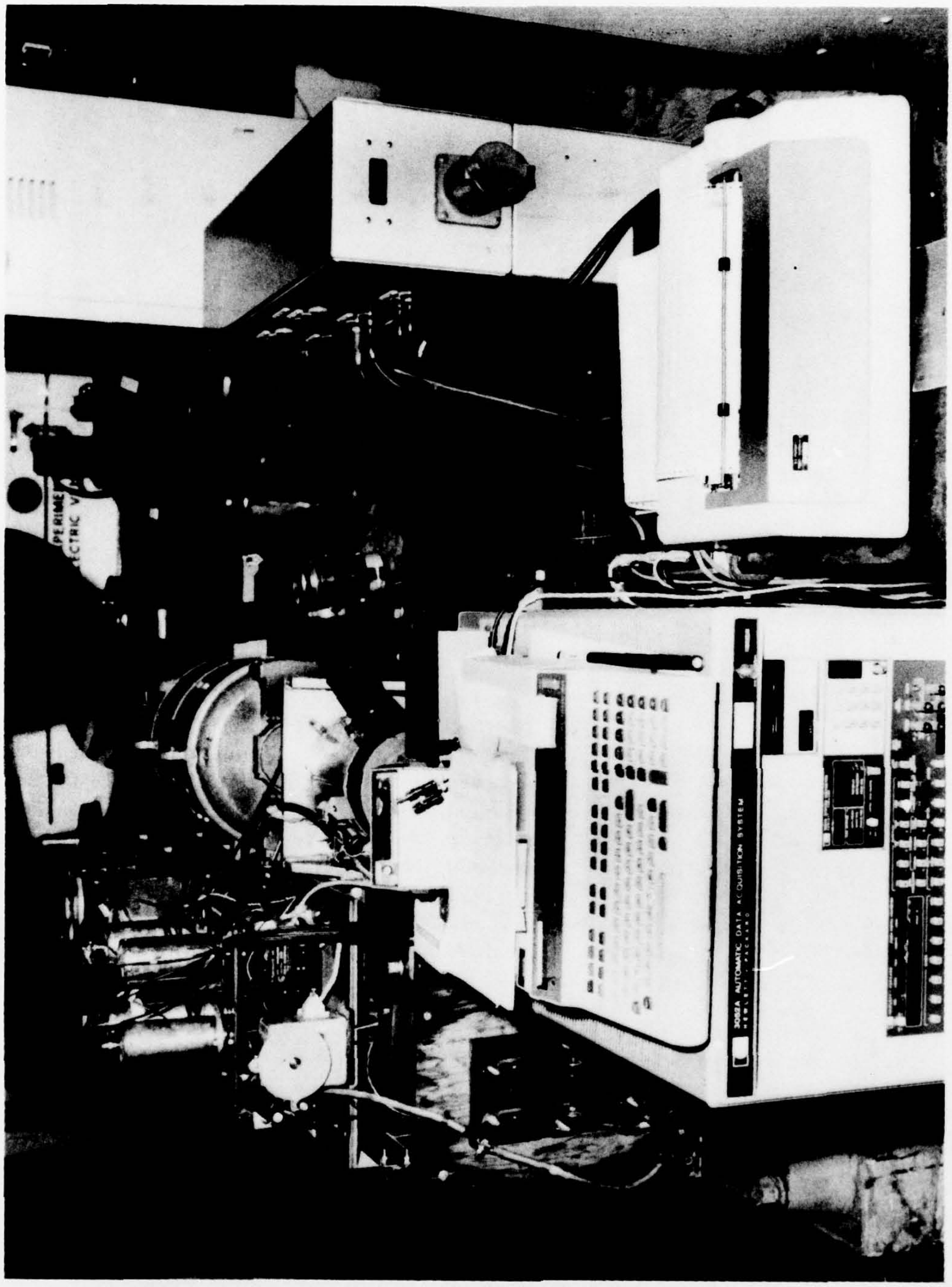


Figure 9.7. Dynamometer No. 3 test facility, overview.

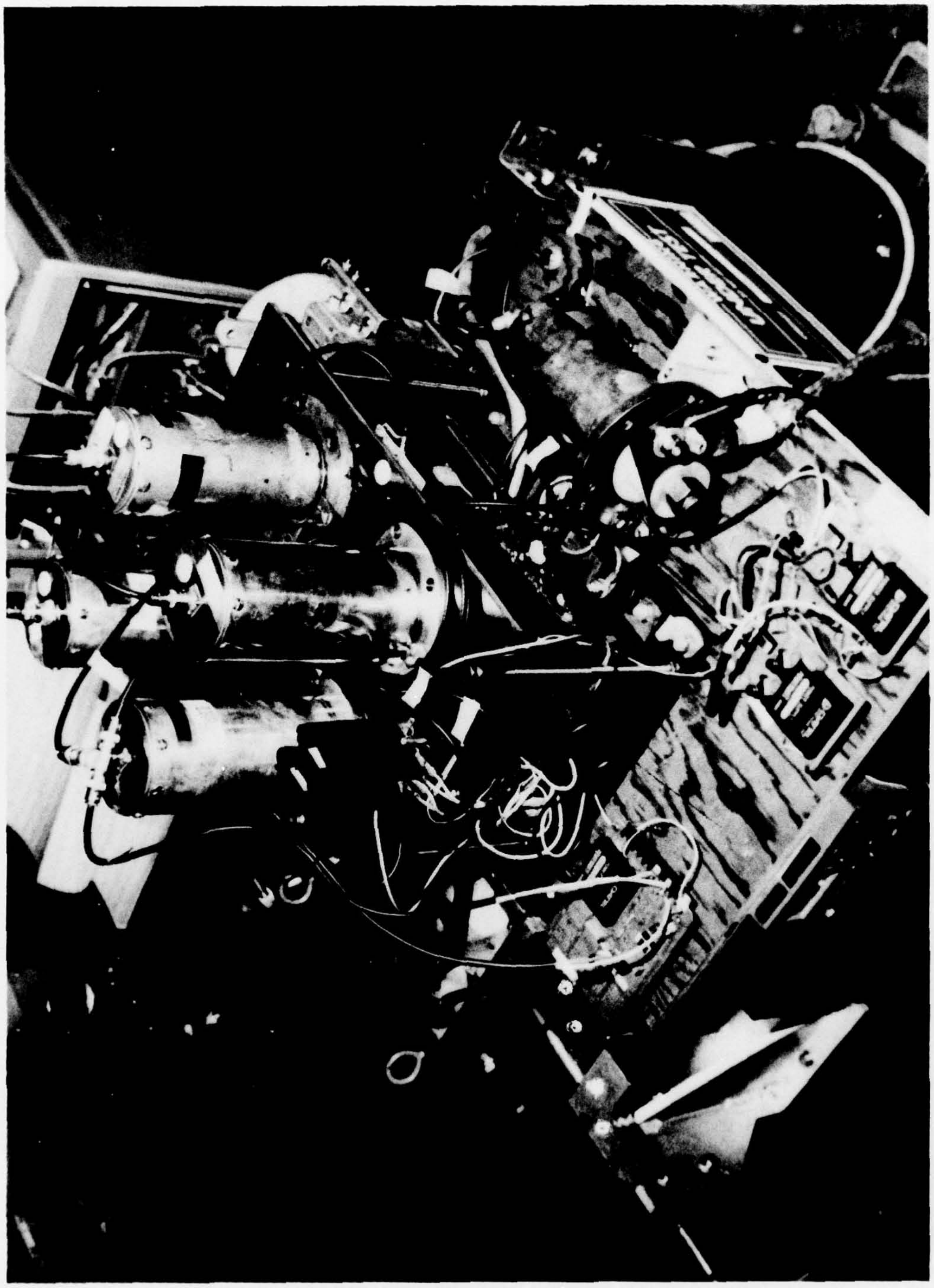


Figure 9.8. Mounting plate for coaxial current shunts on top of DC controller panel.

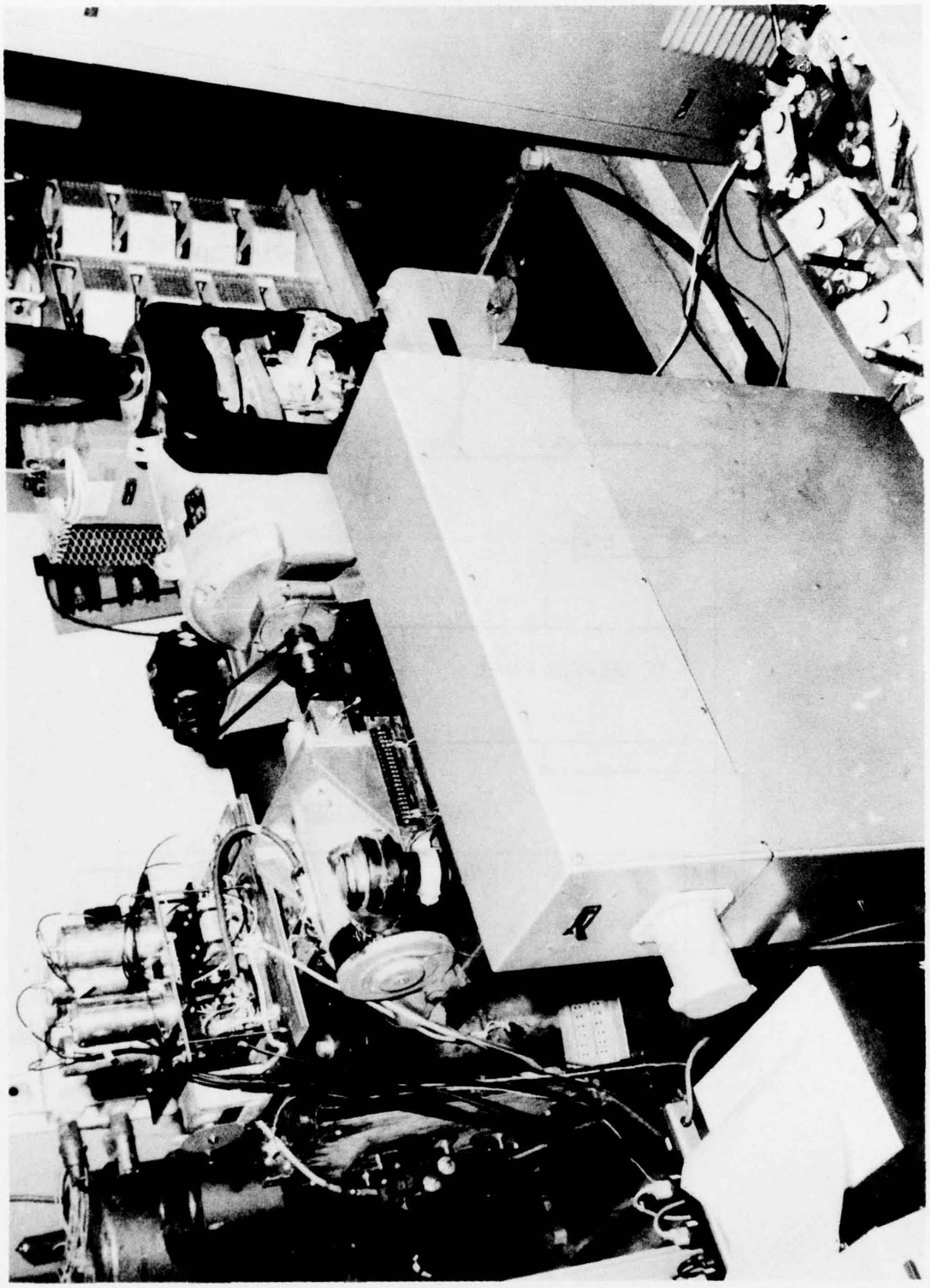


Figure 9.9A. Battery is stored in direct proximity of drive stand No. 3.

EVA #1 METRO SEDAN BATTERY HOOK-UP

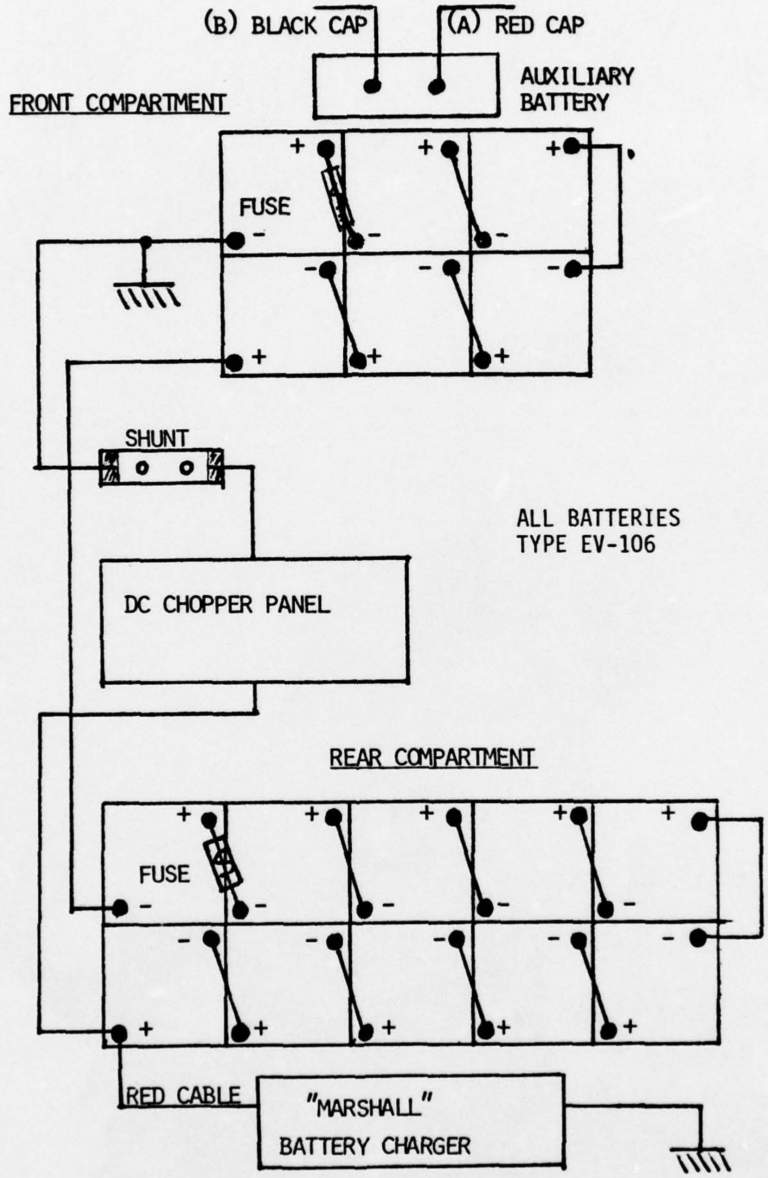
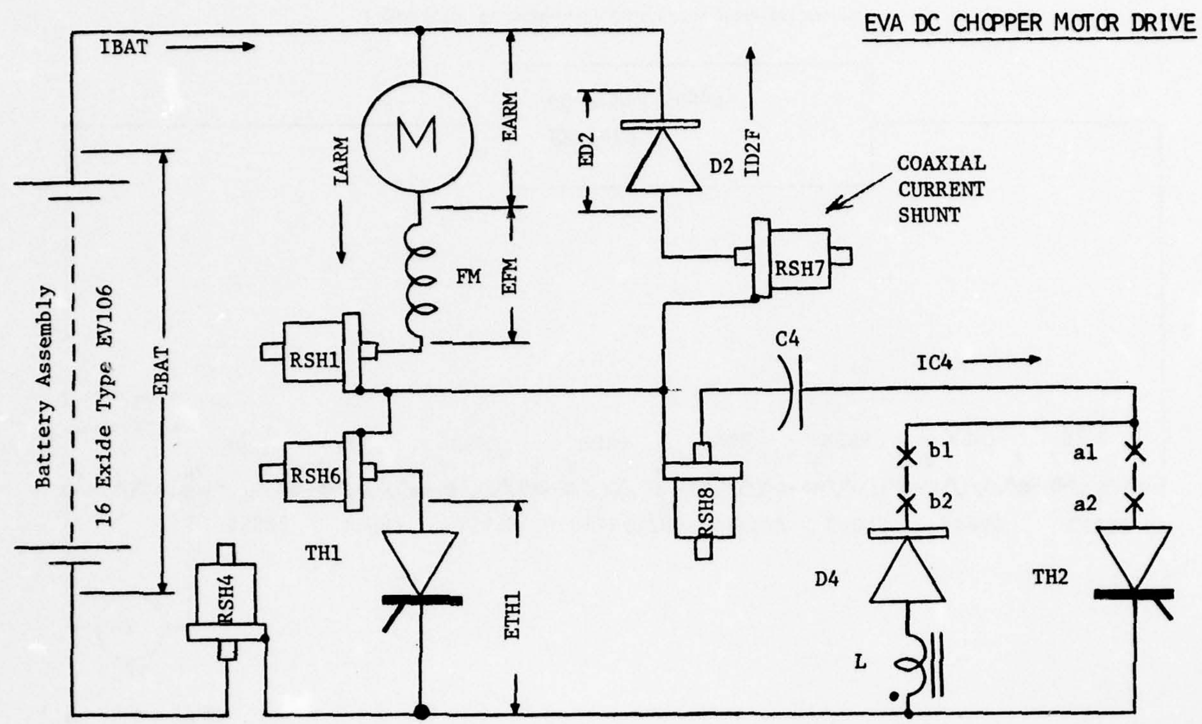


Figure 9.9B. Battery hook-up.



a1, a2: Shunt location for display of commutation current.

b1, b2: Shunt location for display of reset current

Figure 9.10. In-circuit location of coaxial current shunts during testing.

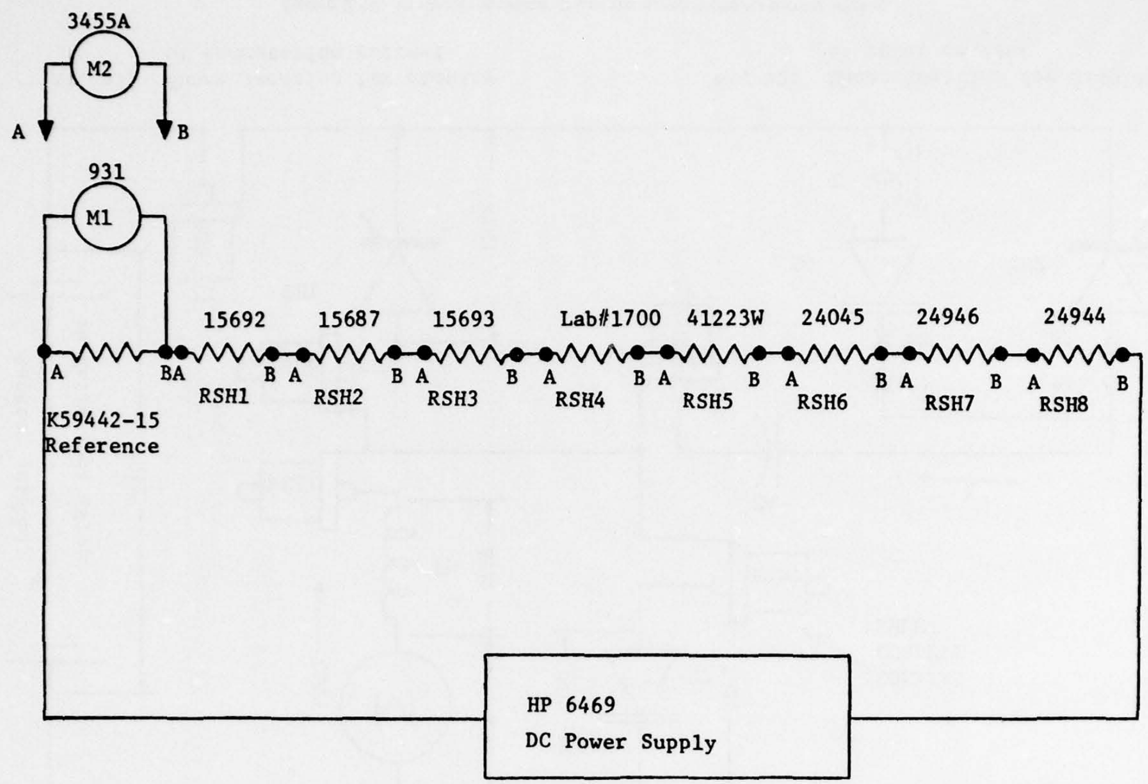


Figure 9.11. Calibration circuit for coaxial current shunts.

TABLE 2: COAXIAL DC CURRENT SHUNT CALIBRATION

DC CURRENT I(A)	Weston Shunts		T&M RESEARCH COAXIAL CURRENT SHUNTS						
	Reference		TERMINAL VOLTAGE VIRSH (mV)						
	V_I REF(mV)	VIRSH5							
	KS9442-15	41223W	15692	15693	15687	#1700	24945	24946	24944
25	12.50	12.47	12.78	12.50	12.44	12.45	12.40	12.42	12.48
50	25.00	24.96	25.57	25.01	24.88	24.91	24.76	24.82	24.94
75	37.50	37.48	38.46	37.60	37.42	37.46	37.09	37.22	37.40
100	50.00	49.64	51.20	50.06	49.80	49.86	49.50	49.69	49.90
CURRENT SYMBOL	IREF	IDLC 1)	IARM	ID4 IFM2	ITH2 IFM1	IBAT	IDLC ITH1	ID2	IC4
SHUNT SYMBOL	RSHREF	RSH5	RSH1	RSH2	RSH3	RSH4	RSH6	RSH7	RSH8
VIREF/V_IRSH	1.000	1.0085	0.9766	0.9988	1.004	1.003	1.01	1.007	1.003
TRUE CURRENT AMPLITUDE			$I = V_I(V) \cdot 2000\ A/V \cdot (V_I REF / V_I RSH)$ (A)						

1) TEST DATA PRIOR TO 1 January 1979

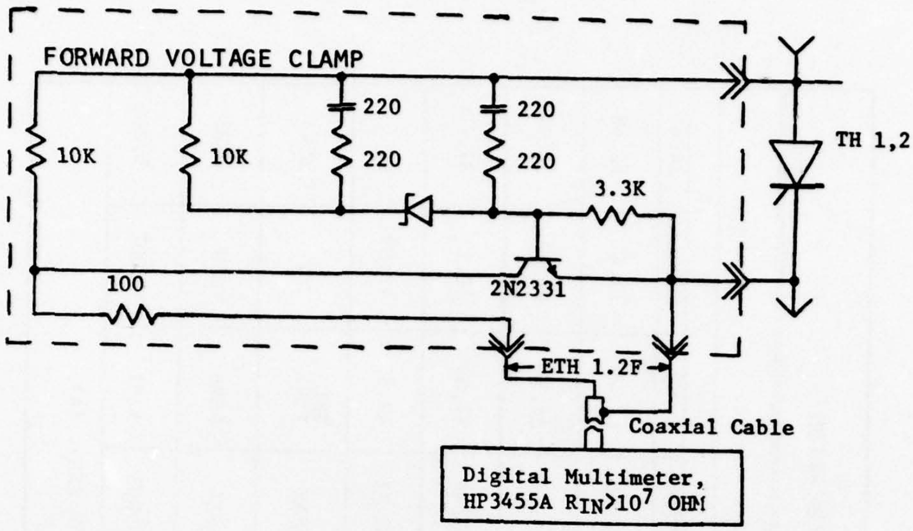


Figure 9.12. Adaptor circuit for measurement of thyristor forward voltage drop.

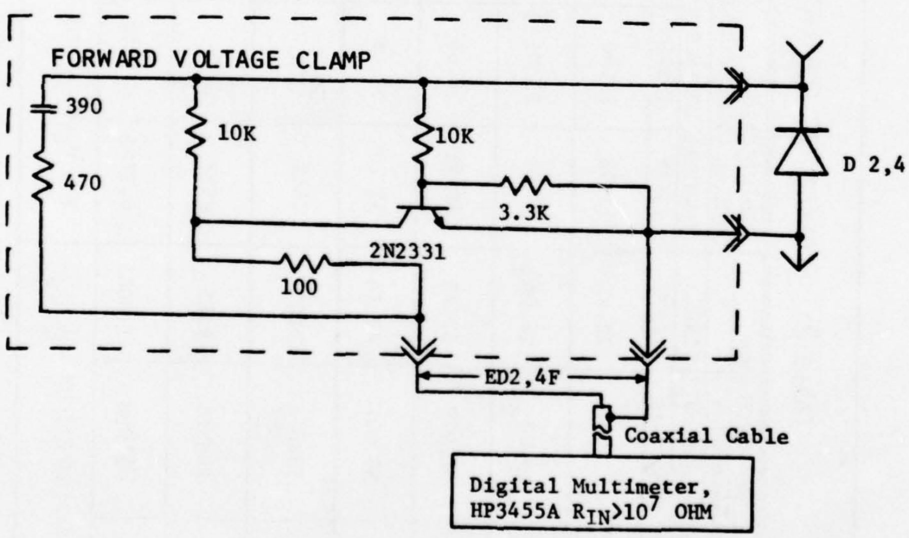


Figure 9.13. Adaptor circuit for measurement of diode forward voltage drop.

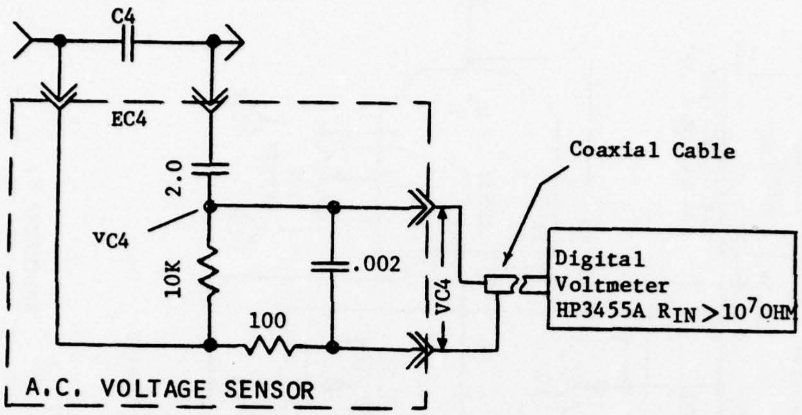


Figure 9.14. Adaptor circuit for capacitor (C4) A.C. voltage sensor.

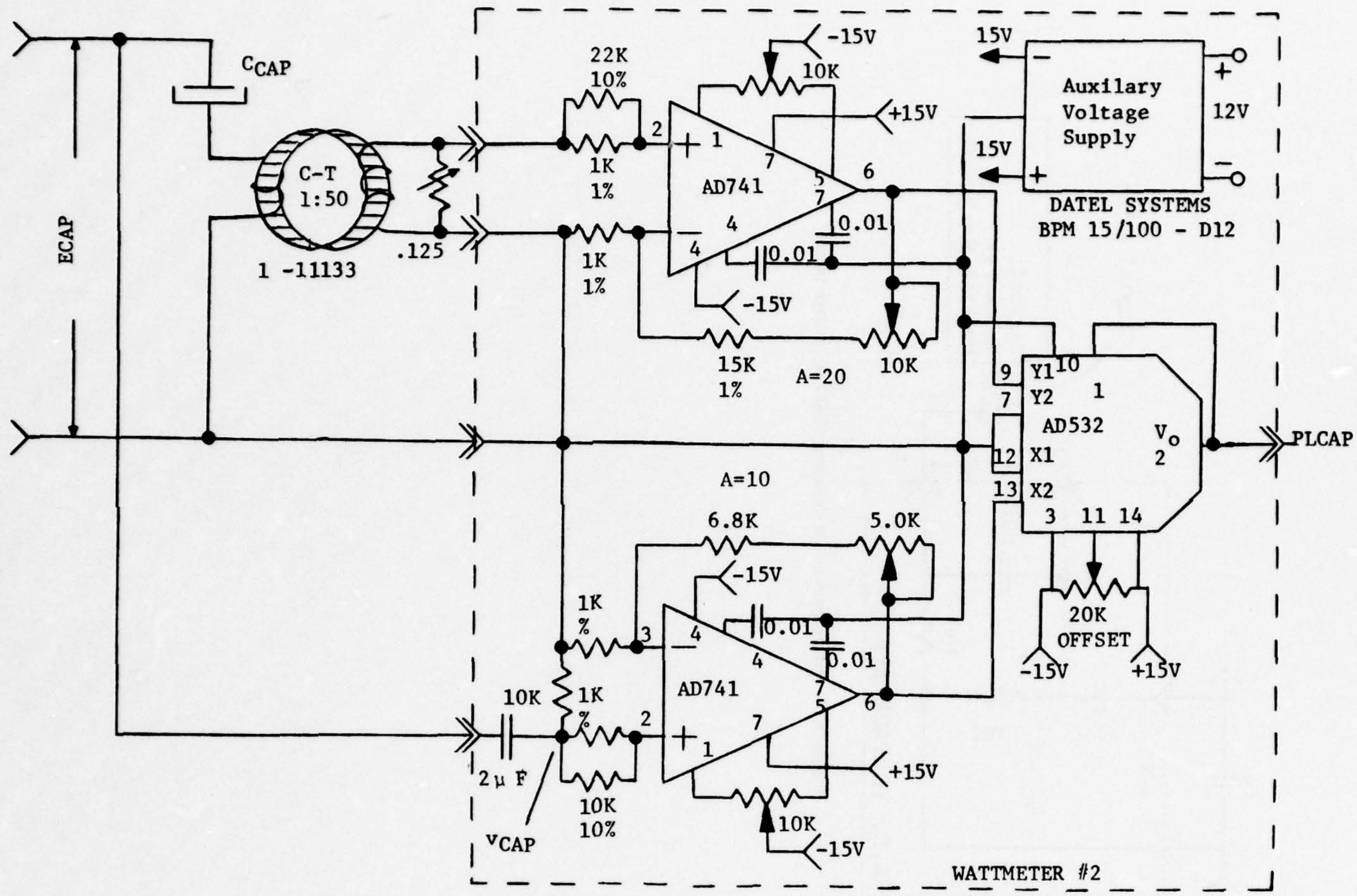
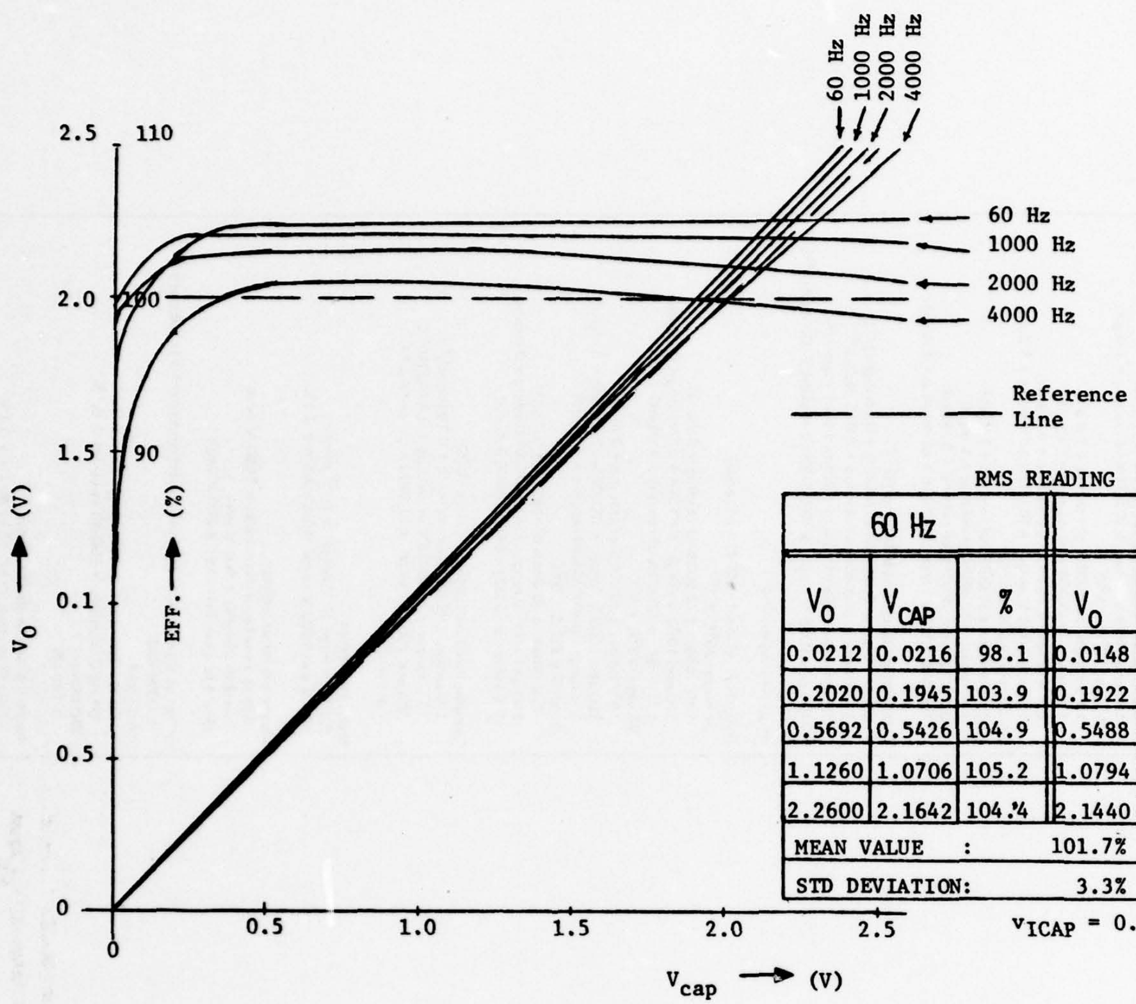


Figure 9.15. Measurement of power loss in capacitor (C4).



RMS READING

60 Hz			4000 Hz		
V_O	V_{CAP}	%	V_O	V_{CAP}	%
0.0212	0.0216	98.1	0.0148	0.0215	68.8
0.2020	0.1945	103.9	0.1922	0.1964	97.9
0.5692	0.5426	104.9	0.5488	0.5449	100.7
1.1260	1.0706	105.2	1.0794	1.0709	100.8
2.2600	2.1642	104.4	2.1440	2.1610	99.2
MEAN VALUE :		101.7%			
STD DEVIATION:		3.3%			

$v_{ICAP} = 0.5V_P$ = CONSTANT

Figure 9.16. Typical calibration curve for wattmeter No. 2.

Table 3. Specifications for HP3455A Digital Multimeter.

(Specifications Apply with AUTO CAL On)

DC VOLTAGE

(High Resolution Off)
Accuracy: (1 digit = .001% of range)
24 hours; 23°C ± 1°C
10 V range: ± (0.002% of reading + 1 digit)
1 V range: ± (0.003% of reading + 1 digit)
0.1 V range: ± (0.004% of reading + 4 digits)
100 and 1000 V range: ± (0.004% of reading + 1 digit)
90 days, 23°C ± 5°C
10 V range: ± (0.005% of reading + 1 digit)
1 V range: ± (0.006% of reading + 1 digit)
0.1 V range: ± (0.007% of reading + 4 digits)
100 and 1000 V range: ± (0.007% of reading + 1 digit)
6 months; 23°C ± 5°C
10 V range: ± (0.008% of reading + 1 digit)
1 V range: ± (0.009% of reading + 1 digit)
0.1 V range: ± (0.01% of reading + 5 digits)
100 and 1000 V range: ± (0.010% of reading + 1 digit)

Temperature Coefficient: (0°C to 50°C)
0.1 V range: ± (0.0003% of reading + 0.15 digits)/°C
1 V range: ± (0.0003% of reading + 0.015 digits)/°C
10 V range: ± (0.00015% of reading + 0.01 digits)/°C
100 and 1000 V range: ± (0.0003% of reading + .01 digits)/°C

(High Resolution On)

Accuracy: (1 digit = .0001% of range)
24 hours; 23°C ± 1°C
10 V range: ± (0.002% of reading + 3 digits)
100 and 1000 V range: ± (0.004% of reading + 3 digits)
1 V range: ± (0.003% of reading + 4 digits)
90 days; 23°C ± 5°C
10 V range: ± (0.005% of reading + 3 digits)
100 and 1000 V range: ± (0.007% of reading + 3 digits)
1 V range: ± (0.006% of reading + 4 digits)
6 months; 23°C ± 5°C
10 V range: ± (0.008% of reading + 3 digits)
100 and 1000 V range: ± (0.010% of reading + 3 digits)
1 V range: ± (0.009% of reading + 5 digits)

Temperature Coefficient: (0°C to 50°C)
1 V range: ± (0.0003% of reading + 0.15 digits)/°C
10 V range: ± (0.00015% of reading + 0.1 digits)/°C
100 and 1000 V range: ± (0.0003% of reading + 0.1 digits)/°C

Input Resistance:
0.1 V through 10 V range: > 10^{10} ohms
100 V and 1000 V range: 10 megohm ± 0.1%

Maximum Input Voltage:
High to Low Input Terminals: ± 1000 V peak
Guard to Chassis: ± 500 V peak
Guard to Low Terminal: ± 200 V peak

Effective Common-Mode Noise Rejection (with 1 kΩ imbalance in LOW lead)
AC Input:
50 Hz Operation: > 160 dB at 50 Hz ± 0.1%
60 Hz Operation: > 160 dB at 60 Hz ± 0.1%
DC Input:
> 140 dB

Normal Mode Noise Rejection:
50 Hz Operation: > 60 dB at 50 Hz ± 0.1%
60 Hz Operation: > 60 dB at 60 Hz ± 0.1%

Table 3. Specifications (Cont'd)

AC VOLTAGE (RMS Converter)

Accuracy: (AC Coupling, input > 1% of full scale)
± (% of reading + digits)[1] (1 digit = .001% of range)

FAST ACV / ACV	300 Hz–20 kHz / 30 Hz–20 kHz	20 kHz–100 kHz / 20 kHz–100 kHz	100 kHz–250 kHz[2] / 100 kHz–250 kHz[2]	250 kHz–500 kHz[2] / 250 kHz–500 kHz[2]	500 kHz–1 MHz[2] / 500 kHz–1 MHz[2]
24 hours; 23°C ± 1°C	.04% + 40 dig.	0.4% + 80 dig.	1.8% + 200 dig.	4% + 400 dig.	5% + 1500 dig.
90 days; 23°C ± 5°C	.05% + 50 dig.	0.5% + 100 dig.	2.0% + 250 dig.	5% + 500 dig.	6% + 2000 dig.
6 months; 23°C ± 5°C	.06% + 60 dig.	0.6% + 130 dig.	2.1% + 300 dig.	5.1% + 600 dig.	6.3% + 2400 dig.

AC/DC coupled or AC coupled with input < 1% of full scale: Add + .05% of reading + 20 digits

[1] Guard must be connected to Low.
On the 1000 V range add 0.01 ppm/volt – kHz.

[2] Frequencies greater than 100 kHz specified on 1 and 10 V ranges only.

Temperature Coefficient: (0°C to 50°C)
AC coupled, input > 1% of full scale: ± (0.002% of reading + 2 digits)/°C
AC coupled, input < 1% of full scale: ± (0.002% of reading + 6 digits)/°C
AC/DC coupled: ± (0.002% of reading + 6 digits)/°C

Input Impedance:
Front Terminals – 2 MΩ ± 1% shunted by less than 100 pF
Rear Terminals – 2 MΩ ± 1% shunted by less than 75 pF

Maximum Input Voltage:
High to Low Terminals: ± 1414 volts peak (Subject to a 10^7 volts – Hz limitation)
Guard to Chassis: ± 500 V peak
Guard to Low Terminal: ± 200 V peak

AC VOLTAGE (Average Converter, Option 001)

Accuracy:
± (% of reading + digits)[1] (1 digits = .001% of range)

FAST ACV / ACV	300 Hz–500 Hz / 30 Hz–50 Hz	500 Hz–1 kHz / 50 Hz–100 Hz	1 kHz–100 kHz / 100 Hz–100 kHz	100 kHz–250 kHz[2] / 100 kHz–250 kHz[2]
24 hours; 23°C ± 1°C	0.47% + 70 dig.	0.32% + 50 dig.	0.09% + 25 dig.	0.70% + 60 dig.
90 days; 23°C ± 5°C	0.50% + 70 dig.	0.35% + 50 dig.	0.1% + 25 dig.	0.75% + 60 dig.
6 month; 23°C ± 5°C	0.50% + 70 dig.	0.40% + 60 dig.	0.1% + 30 dig.	0.75% + 70 dig.

[1] Guard must be connected to Low
On the 1000 V range, add 0.01 ppm/volt–kHz.
Specifications are for input levels above 1/100th of range.

[2] Frequencies greater than 100 kHz specified on 1 and 10 V ranges only.

Temperature Coefficient: (0°C to 50°C)
± (0.002% of reading + 2 digits)/°C

Input Impedance:
Front Terminals – 2 MΩ ± 1% shunted by less than 100 pF
Rear Terminals – 2 MΩ ± 1% shunted by less than 75 pF

Maximum Input Voltage:
High to Low terminals: ± 1414 volts peak (Subject to a 10^7 volts – Hz limitation)
Guard to Chassis: ± 500 V peak
Guard to Low Terminal: ± 200 V peak

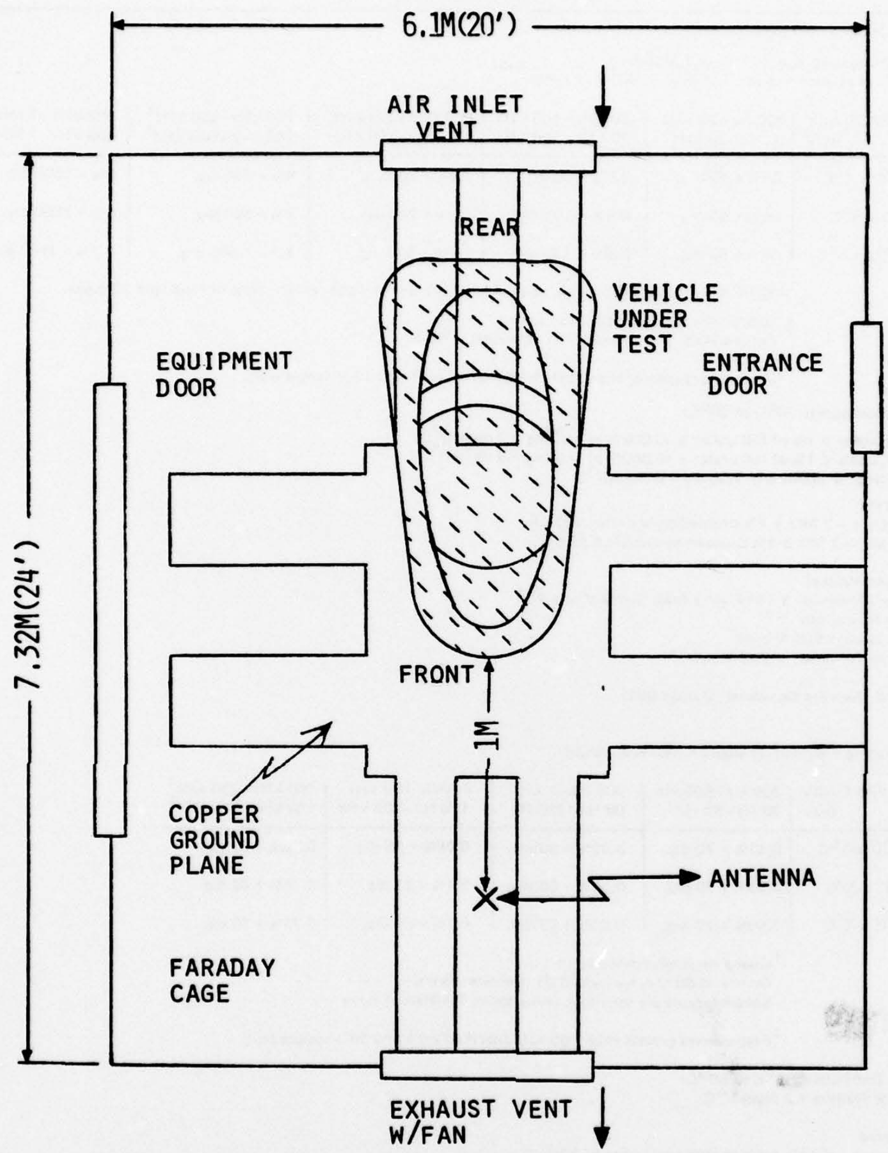


Figure 9.17. Shielded enclosure for EMI test.

An FSS 250 Fairchild Electro Metrics Computer Controlled Surveillance System S/N 69 was used during this investigation comprising the components shown in Table 4. The EVA Metro Sedan was tested at three vehicle chopper/motor current levels:

a. 50 Ampere DC current draw w/vehicle in neutral.

b. 50 Amp current draw w/vehicle in gear – brake on.

c. 200 Amp current draw w/vehicle in gear – brake on.

6. Sound Level. Sound levels were recorded again before vehicle disassembly with the microphone positioned in the center of the vehicle, between the front seats at a height equal to the top of the seats. Levels were recorded for three different conditions as follows:

1. The vehicle was driven over an asphalt roadway at the speed of 32 to 40 kilometers (20 to 25 miles) per hour. The motor current during this test fluctuated between 100 and 150 amperes.

2. The vehicle was energized in the drive mode with brakes in locked position. The battery current was held at constant 100 amperes.

3. The same as condition #2 with the battery current at constant 200 amperes.

Instrumentation shown in Table 5 was used to determine sound levels during this test. The instrumentation was calibrated with traceability to the National Bureau of Standards.

7. Motor Rotor Inertia. To aid theoretical analysis to optimize the gear ratio between the motor and the wheels, the motor rotor inertia test was performed on the original equipment motor prior to its return to Electric Vehicle Associates, Inc. Figure 9.18 shows schematically the test configuration used to measure rotor inertia. Inertia tests were conducted first with the rotor and end bell combined (J1), and then only for the end bell (J2). Rotor inertia was calculated from $J_M = J_1 - J_2$, as shown in equation (9.1):

$$J_{1,2} = \left(\frac{T}{2\pi} \cdot a\right)^2 \cdot \frac{W}{L} \quad \text{(lb ft s}^2\text{)} \tag{9.1}$$

$$= (T \cdot a)^2 \cdot \frac{W}{L} \cdot 1.066 \cdot 10^{-3} \quad \text{(mkg s}^2\text{)}$$

whereby:

T = duration of one oscillatory cycle(s)
a = distance between two parallel wires suspended from the ceiling (ft)
L = Length of the suspended wires (ft)
W = weight of test sample (lb)

Table 4: Instrumentation to Determine EMI

1. EMC-25 Receiver, Fairchild Electro Metrics, S/N 350378R-4.

2. EMC-10 Receiver, Fairchild Electro Metrics, S/N 10452.

3. RVR 41" Whip Antenna, Fairchild Electro Metrics, (covering frequency range .014 Khz, through 25 Mhz), S/N 378.

4. VHF Broadboard(Biconical)Antenna, Stoddard, (covering frequency range of 25 Mhz through 210 Mhz), S/N 35.

5. Spiral Cone (Log Conial) Antenna, Stoddard, (covering frequency range of 200 Mhz through 1 Ghz), S/N 122.

6. SF 125 Antenna Switching Unit, Fairchild Electro Metrics, S/N 93.

7. Digital Interface Unit Model D1U-125, S/N 113.

8. Digital Step Attenuator Model DSA-125, S/N 101.

9. Tektronix Computer Model 5051 S/N B092189.

10. Tektronix Hard Copy Unit Mdl 4631, S/N B136617.

Table 5: Instrumentation to Determine Sound Level

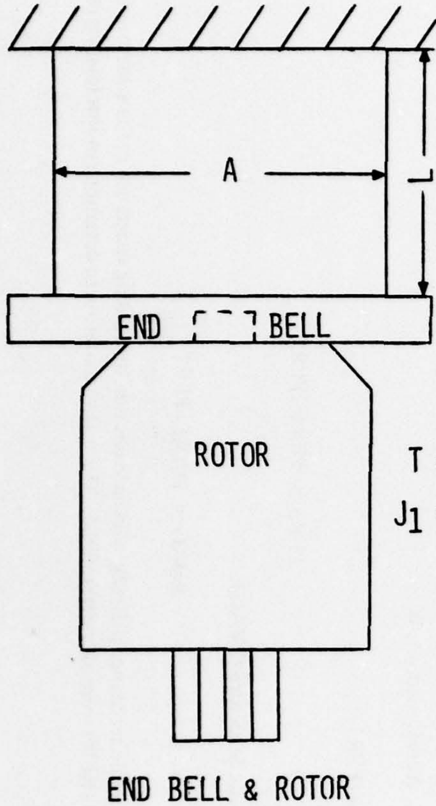
1. Sound Level Meter, B&K Model 2209, Serial 595136.

2. Octave Band Analyzer, B&K Model 1613, Serial 601489.

3. Graphic Level Recorder, B&K Model 2306, Serial 631587.

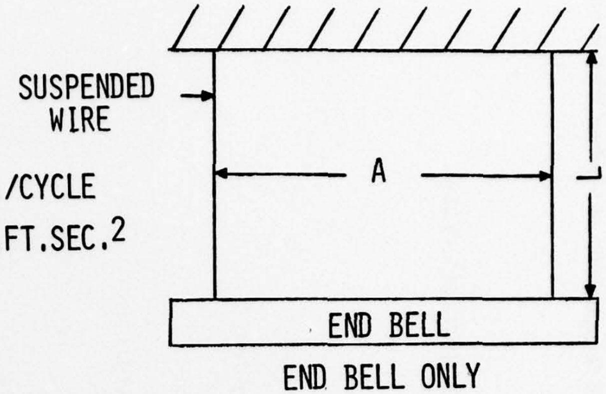
4. Microphone, B&K Model 4165, Serial 599672.

5. Calibrator, B&K Model 4230, Serial 596244.



T = 2.64 SEC./CYCLE

J_2 = 0.212 LB.FT.SEC.^{2}



T = 1.87 SEC./CYCLE

J_1 = 0.335 LB.FT.SEC.^{2}

	A INCH	A FT.	L INCH	L FT.	WEIGHT LB.
END BELL & ROTOR	9.25	0.771	116.75	9.73	62.0
END BELL ONLY	10.00	0.883	116.25	9.69	16.8

Figure 9.18. Motor rotor inertia test.

8. **Motor Power Loss.** Motor losses other than the electrical ($I^2 R$) winding losses within the machine were measured with the test circuit shown in Figure 9.19, and the instrumentation package shown in Table 7. Equations (9.2) to (9.5) show the methods for determination of windage, friction and magnetic losses vs. speed or flux level.

Windage, Friction and Magnetic Loss (PCOR):

$$PCOR = (A1 \cdot V1) - (A1^2 \cdot RARM) - (A1 \cdot VBR) \quad (W) \tag{9.2}$$

whereby:

RARM	=	Armature resistance, ohm
VBR	=	Brush voltage drop, VDC
A1	=	Armature current, A dc
V1	=	Armature voltage, including brush voltage drop, V dc

Windage and Friction Loss (PFR1), motor winding disconnected:

$$PFR1 = PFR1' - PQO3 \quad (W) \tag{9.3}$$

whereby:

PFR1'	=	Actual readout, W
PQO3	=	Dynamometer #3 tare power readout, W

Windage and Bearing Loss, only (PFR2), brushes removed:

$$PFR2 = PFR2' - PQO3 \tag{9.4}$$

whereby:

PFR2'	=	Actual readout, W

Brush Friction Loss (PFR3):

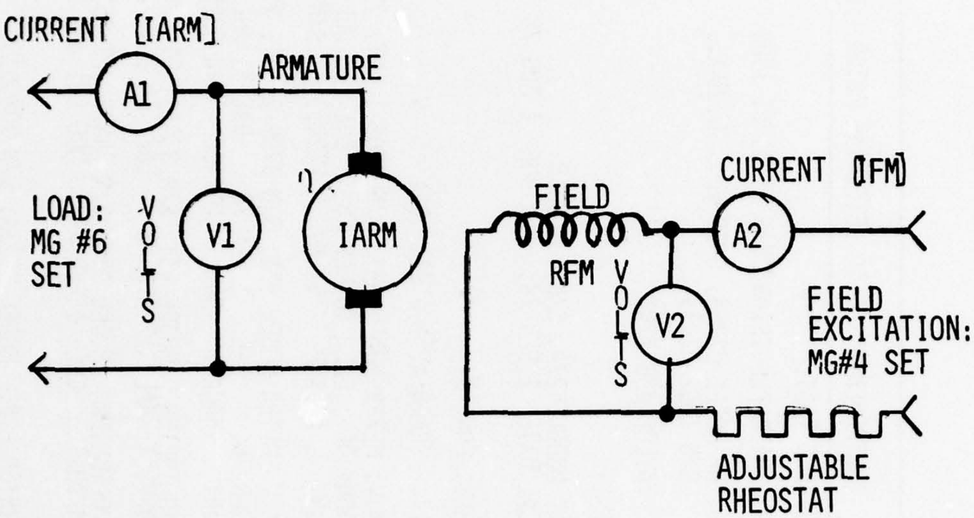
$$PFR3 = PFR1 - PFR2 \quad (W) \tag{9.5}$$

Watt-Loss in Magnetic Structure (PMAG):

$$PMAG = PCOR - PFR1 \quad (W)$$

By measuring the ohmic resistance digitally, power losses due to winding resistance in the armature (RARM) and the series field (RFM) were also determined. The instrumentation to determine motor losses is described in Table 6.

MOTOR: BALDOR DC SERIES FIELD
#1276 FRAME 215CZ 7544D
10HP/3800RPM 84VDC/98A



ARMATURE RESISTANCE: RARM = 0.0064 OHM

FIELD RESISTANCE (BRUSHES REMOVED): RFM = 0.0097 OHM @ 24°C

BRUSH VOLTAGE DROP (VBR): VBR = F(IARM)

Figure 9.19. Windage, friction and magnetic loss test (PCOR)

TABLE 6: INSTRUMENTATION TO DETERMINE MOTOR LOSSES
WINDING RESISTANCE TEST:
VOLT-OHMMETER: DATA PRECISION, S/N 2150, PT 1588
POWER SUPPLY: HP MODEL 6226B, 0-50 VDC, 1A MAX., S/N 1502A02113
THERMOMETER: TAYLOR #3697743
BRUSH LOSS TEST:
VOLTMETER: HP MODEL 427A, S/N 62103018 CAL DATE 2 FEB 78, CAL DUE 1 AUG 78
MOTOR LOSS TEST, CONT'D:
PCOR = (A1·V1) - (RARM·A1^2) - (A1·VBR) W
A1: WESTON M.V. METER MODEL 931, S/N 3709-1, PT. 2526, F.5. = 50MV DC CAL 10 FEB 78 DUE 13 JUL 78 WITH SHUNT 300AMP 50 MV PT2433 S/N 0025237
A2: WESTON M.V. METER MODEL 931, S/N 3709-2, PT. 2525, F.5. = 50MV DC CAL 1 FEB 78 DUE 31 JUL 78 WITH SHUNT 300AMP 50MV PT2429 S/N 0025237
V1: WESTON VOLTMETER MODEL 931, S/N 83412, PT 2882 1000 OHM/VOLT CAL 17 APR 78 DUE 14 OCT 78
V2: WESTON VOLTMETER MODEL 931, S/N 74827, PT 2520 5000 OHM/VOLT CAL 1 FEB 78 DUE 31 JUL 78
AUTOMATIC COUNTER H.P. MODEL 5323A, S/N 90800150 PT. 2899, CAL DATE 13 JAN 78 DUE 18 JUL 78

3/11 MAY 78

9. **Battery Energy Transfer Efficiency.** The evaluation of energy transfer efficiency of a six-volt propulsion battery similar to the type EV-106 was performed by contract (Ref. 5) under separate funding authority. For this purpose a battery manufactured by the Prestolite Company, Model 9915-X, Serial 001639, 75 A-H @ 110 minutes, was utilized. Gas leakage and pressure was controlled by a pressure snubber and an improvised inclined manometer using a 2.5 ccm hypodermic syringe with the plunger removed to allow gas leakage when the hypodermic needle was inserted into the filler cap of the center cell. The gas evolution automatic response circuit consisted of a leaky toy balloon which in turn opened a micro-switch when the gas pressure exceeded typically 0.5" water pressure through a calibrated orifice. The gas pressure itself was continually released through a porous metallic screen, or the pressure snubber (Cat. #25-S, ¼" nptf, Porosity E, Chemiquip Co.).

The circuit arrangement, shown in Figure 9.20, utilizes an adjustable thyristor controlled battery charger which is alternately turned on and off by the balloon pressure activated micro-switch. In the charge mode dc power is drained from the donor battery (B2) during the boost mode of the battery charger, while in the discharge mode battery connections are reversed such that B2 becomes the receiver and battery (B1) the donor. Inasmuch as the peak current amplitude is an uncontrolled variable and relatively constant in magnitude, the magnitude of the average current is a function the conduction duty cycle of the micro-switch.* Table 7 identifies the instrumentation package used for this test.

X. RATIONALE FOR EVALUATION OF POWER TRANSFER

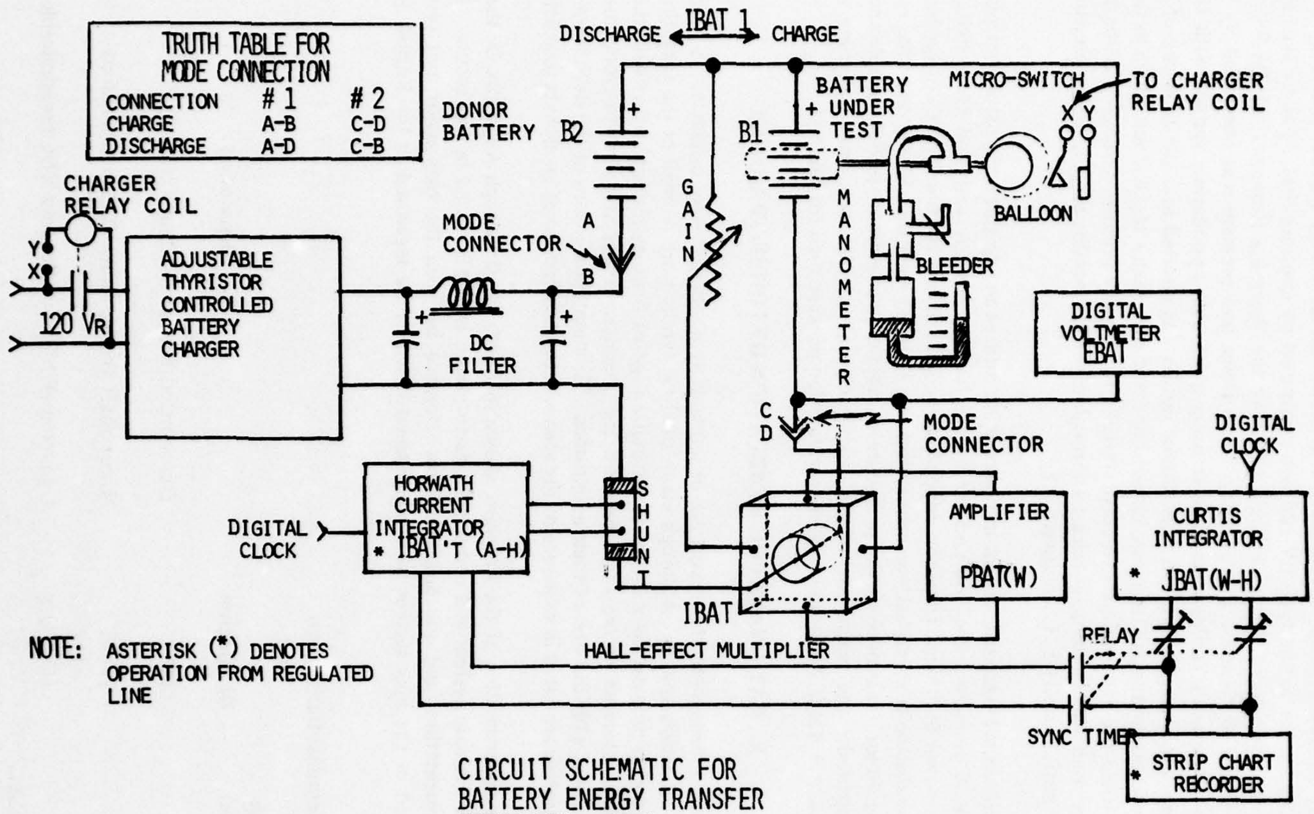
Data presented throughout this report are in terms of symbols that were originated to be compatible with the data acquisition system. Although many of these symbols are defined in the text, the following scanner designation is provided as a complete centralized list of these symbols together with their description for reference. Because of cross-talk between the channels, it was necessary to group the incoming signals in accordance with the size of their amplitudes. To maintain a record of the utilization of scanner channels, the symbols are listed in sequence of the scanner channels instead of an alphabetical listing.

To aid the understanding of the software, shown in Appendix B through Appendix D, the complete test rationale to evaluate system and component performance is also included in this section. Because of available instrumentation, and the desirable cross-reference between the two major unit systems, data usually measured in the mks system were supplemented with data measured in the English unit system when feasible.

1. Scanner Terminal Designation

Scanner Channel	Designation	Description	
0	TO	Transmission Torque Readout	VTO V
1	TMOT	Motor Shaft Torque (Into VDC Transmission)	
2	TQ, TQ.)	Dynamometer Torque Readout VDC (as applicable)	

* A continuously adjustable dc current amplitude would have been clearly preferable at this juncture, but was outside the equipment capability available for this low budget effort.



CIRCUIT SCHEMATIC FOR
BATTERY ENERGY TRANSFER
EFFICIENCY TEST
FIGURE 9.20

TABLE 7 : INSTRUMENTATION FOR BATTERY TEST

DESCRIPTION	MFG	MODEL	RATING	USE
REGULATED SINGLE CELL THYRISTOR CHARGER	LOCAL		2.5 V/25A	VOLTAGE BOOST
HEAVY DUTY BATTERY ASSEMBLY	C&D		6V/450AH	B2
DIGITAL V-OM	MICRONTA	22-200 #A00 1985	1000/100/10/1V	EBAT
MANOMETER	DWYER	1230-8	0-8" H_2O	GAS PRESSURE
PRESSURE SNUBBER	CHEMIQUIP	25-S	POROSITYE	GAS LEAKAGE
AMPERE-HOUR INTEGRATOR	HORWATH	MPH 500 A-H	12 V & .005V* INPUT	A-H MEASUREMENT
HALL-EFFECT MULTIPLIER	OHIO SEMITRONICS	CT400LTT	109.9MA = 50MV*	PBAT
AMPLIFIER		AP3-88-1	1:1	
CHART RECORDER CHARTS	AMPROBE AMPROBE	LDM 1850 85 OD	12 IN/H*	
DIGITAL CLOCK	GE TELECHRON		CYCLOMETER HOURS/MINUTES	TIMING

TABLE 7: INSTRUMENTATION FOR BATTERY TEST (CONT'D)

DESCRIPTION	MFG	MODEL	RATING	USE
SYNC TIMER	GEN. TIME	D21A0026	57 SECONDS	INTERVAL
SYNC TIMER	GEN. TIME	EN30054	ON: A; OFF: W	
WATT-HOUR INTEGRATOR	CURTIS INSTRUMENTS	1002-50-1	50A/.1V*	JBAT
SHUNT	RAM METER		50MV/150A	IBAT
RELAY	POT. & BRUMF.	KRP11A	DPDT	W-A THROW OVER
BALLOON		TDY	0.5 IN. OF WATER	SWITCH ACTUATOR

NOTE: ASTERISK (*) DENOTES CALIBRATION IN EFFECT

Scanner Channel	Designation	Description	
3		Solenoid 1, On-Off	
4		Solenoid 2, On-Off	Vdc
5	TEMP T	Transmission Temperature	Vdc
6	TEMP M	Motor Temperature	Vdc
7			
8			
9			
10	EBAT	Battery Terminal Voltage	Vdc, RMS
11	EARM	Motor Armature Voltage	Vdc, RMS
12	EFM	Motor Field Voltage	Vdc, RMS
13	ETH1	"On-Voltage Drop in Thyristor (TH1) (with FWD Voltage Clamp)	Vdc, RMS
14	ED2F	On-Voltage Drop in DIODE(D2) Over One Conduction Cycle (with FWD Voltage Clamp)	Vdc, VRMS
15	VC4	Capacitor (C4) AC Voltage (Via Adaptor Circuit)	VRMS
16	PLABT′	Power Loss Within Battery When Discharging	W DC
	PLBAT′	(Via Wattmeter 1)	W RMS
17	PLCOM	Power Loss in Commutating Circuit (Via Wattmeter #3)	W RMS
18	PLAC4	Power Loss in Capacitor	W DC
19	PLC4	(Via Wattmeter 2)	W RMS
20	IBAT′	Battery Current (Shunt RSH4)	mVdc, RMS

Scanner Channel	Designation	Description	
21	IARM	Armature Current (Shunt RSH1)	mVdc,RMS
22			
23	ITH1	Thyristor TH1 Current (Shunt RSH6)	mVdc, RMS
24	ID2	Diode D2 Current (Shunt RSH7)	mVdc, RMS
25	IC4	Capacitor C4 Current (Shunt RSH8)	mV,RMS
26	ITH2	Thyristor TH2 Current (Shunt RSH3)	mV,RMS
27	ID4	Diode D4 Current (Shunt RSH2)	mV,RMS
28	VCT1	Contactor Forward Voltage Drop	mVdc mVRMS
29			
30			
31			
32			
33			
34	NTR	Motor Rotor Speed	(Frequency)
35	NQ1	Wheel Speed	(Frequency)
36	CONTR	Control Frequency	(Frequency)
37			
38			
39			

2. **Data Print Out**

Designation	Description	
P1	DC Power Loss in Coaxial Current Shunts RSH1 & RSH6	W DC
P2	DC Power Loss in Coaxial Current Shunt RSH RSH4	W DC
P3	As P1, Except RMS Power	W RMS
P4	As P2, Except RMS Power	W RMS
PABT	Average Power at Battery Terminal	W DC
PBAT	RMS Power at Battery Terminal	W RMS
PLABT	Average Power Dissipation Within Battery	W DC
PLBAT	Power Loss Resulting in Battery Heating	W RMS
ΔMOT	Conduction Duty Cycle of Main Switch, TH1	
ΔD2F	Conduction duty cycle of Free-Wheeling Diode, D2	
DFM	Resistive Voltage Drop Across DC Series Field	Vdc VRMS
PAMOT	Average Power Consumption of Motor	W DC
PMOT	RMS Power Consumption of Motor	W RMS
PTR	Motor Power Delivered at Shaft	W DC
PLMOT	Power Loss in Motor	W RMS
ηMOT	Motor Efficiency	[%]
WLMOT	Motor Power Loss Per Unit Torque @ Constant Speed	WL/N-m
PO	Power Available from transmission	W DC
PAMTR	Average Power from Controller	W DC
PACTR	Average Power Loss Within Controller	W DC
PLCTR	RMS Power Loss in Controller	W RMS
ηCTR	Controller Conversion Efficiency	%

Designation	Description	
WLCTR	Controller Power Loss/N-m Torque	WL/N-m
PATH1	Average Power Loss in Thyristor TH1	W DC
PTH1	RMS Power Loss in Thyristor TH1	W RMS
PAD2F	Average Power Loss in Diode D2	W DC
PLD2F	RMS Power Loss in Diode D2	W RMS
PAEV	Power Requirement for Electrical Drive System w/o Transmission	W DC
ηEV	Conversion Efficiency of Electrical Drive System	%
PHEAT	Power Loss of Electrical Drive Resulting in Heating	W RMS
PEVA	Power Requirement for Electrical Drive System Including Transmission	W DC W RMS
ηEVA	Power Transfer Efficiency for Entire System	%
WLEVA	Power Loss Per Unit Torque Delivered to the Wheel for Entire System	WL/N-m
NSL	Slip	%
SL	Slip Frequency	HZ
ηTR	Transmission Efficiency	%
WLTR	Power Loss Per Unit Torque Delivered to the Wheel, Transmission Only	WL/N-m
vrsh	Read Out Voltage Across Coaxial Current Shunts, add Suffix	V
vtQ1	Read Out Voltage Across Torque Transducer, Test Stand #1	mV
vtR	Read Out Voltage Across Torque Transducer, Input	V
vtO	Read Out Voltage Across Torque Transducer, Transmission Output	V
vo	Read Out Voltage of Wattmeter Module, add Suffix	V
RSH	Coaxial Current Shunt Designation, add Suffix	
MOT	DC Motor Designation	

3. Three Speed Automatic Transmission Performance

Read Ametek Torque transducer and dynamometer torque sensor. Compare for discrepancy. Read data for each gear ratio (GR):

Solenoid 1	Solenoid 2	Gear Ratio	Approximate Torque (Max) in Terms of 10HP DC Machine	Designation
0	0	GR3 = 3.45: 1	TQ3 max = 49.2	FT-LB
0	12V	GR2 = 5.13: 1	TQ2 max = 70.9	FT-LB
12V	12V	GR1 = 8.30: 1	TQ1 max = 114.7	FT-LB

Read data for NTR = constant @ TMOT = parameter

(10.1)	TQ	= 13,316 (vtQ - 0.0012)	(Reference data only)	FT-LB
(10.2)	TO	= 50 vtQ · 1.3558		N-m
(10.3)	TMOT	= 8.333 vtR - 1.3558		N-m
(10.4)	NSL	= [(NTR - GR·NO)/NTR] · 100		%
(10.5)	SL	= (NTR·NSL/100)/60		HZ
(10.6)	PO	= (TO · NO)/(5252 · 1.3558)		HP
(10.7)	PO	= 745.7 · (TO·NO)/(5252 · 1.3558)		WDC
(10.8)	PTR	= (TMOT · NTR)/(5252 · 1,3558)		HP
(10.9)	PTR	= 745.7 (TMOT · NTR)/(5252 · 1.3558)		WDC
(10.10)	ηTR	= (PO/PTR) · 100		%
(10.11)	WLTR	= (PTR-PO)/TO		WL/N-m

Performance equations are written to analyze motor performance with power supplied from a dc source, shown in Figure 9.5, or with power supplied from a pulsating power source, e.g.; the chopper schematically shown in Figures 7.1 and 9.6. Motor test data are printed out at regular constant speed intervals (NTR) as function of motor shaft torque (TMOT), and as shown in Appendix I. This comparative testing makes it possible to analyze degradation of motor performance for any other than pure dc power operating conditions.

4. DC Motor Performance

DC power is obtained from an adjustable autotransformer (variac) via a three phase, full wave rectifier. Equations (10.12) to (10.15) define motor performance as a function of motor shaft torque (TMOT) for a family of discrete but constant motor speeds (NTR = constant).

(10.12)	PTR	=	(745.7 · TMOT · NTR)/(5252 · 1.3558)	W DC
(10.13)	PAMOT	=	EMOT · IARM	W DC
(10.14)	ηMOT	=	(PTR/PAMOT) · 100	%
(10.15)	WLMOT	=	(PAMOT - PTR)/TMOT	WL/N-m

whereby:

IARM = v_{RSH1} · 2000 A/V · K1
K1 = 0.9766, shunt correction

5. DC Controller Motor Drive

DC power, as obtained from an energy storage battery, is converted into pulsating power. Power transfer is now measured in terms of energy depleted from the battery and heat loss in the dc motor as well as the other components of the propulsion system. To determine true losses, extraneous losses induced by the measurement apparatus must be identified.

Equations (10.16) to (10.19) identify losses in coaxial dc current shunts:

$$P1 = \sum^{I} [v^2_{RSH} \cdot 2000 \text{ A/V} \cdot K] \qquad \text{[WDC]}$$

$$= \sum^{I} [I^2(2000 \cdot K)] \qquad \text{[WDC]}$$

(10.16) $$P1 \cong [I^2 \text{ ARM}/0.9766 + I^2 \text{ TH1}/1.01/2000 \text{ A/V} \qquad \text{[WDC]}$$
Losses in RSH8 [IC4] not considered

(10.17) $$P2 = (I^2 \text{ BAT}'/1.003)/2000 \text{ A/V} \qquad \text{[WDC]}$$

(10.18) P3 = P1 } except I^2 in (ARMS) [WDC]

(10.19) P4 = P2 } except I^2 in (ARMS) [WRMS]

whereby:

IBAT' = v_{RSH4} · 2000 A/V · K4
K4 = 1.003, shunt correction constant

Power available at the battery terminal is calculated from equation (10.20) to (10.23):

(10.20) $PABT = EBAT \cdot IBAT' - P1 - P2$ [WDC]

(10.21) $IBAT_{[AVG]} = [PABAT/(EBAT \cdot IBAT')] \cdot IBAT'$
$= PABAT/EBAT$ [ADC]

(10.22) $PBAT = [EBAT \cdot IBAT'/\sqrt{\Delta MOT}]_{[AVG]} - P3 - P4$ [WRMS]

(10.23) $IBAT_{[RMS]} = PBAT/EBAT_{[RMS]}$ [ARMS]

For rectangular current pulses the forward conduction duty cycle (Δ) for thyristor TH1 and inverse bypass diode D2 is determined indirectly with equations (10.24) and (10.25).

(10.24) For TH1: $\Delta MOT = (I^2\, BAT_{[AVG]}/I^2\, BAT_{[RMS]})$

(10.25) For D2: $\Delta D2 = (1 - \Delta MOT)$

As shown in Figure 9.10, energy is expended locally through inverse bypass diode D2 and coaxial current shunt RSH1 during the freewheeling operating mode (TH1 is "off"). In equation (10.26) the average voltage drop in D2 is added to the actual measured voltage amplitude EFM. Because of integral assembly of the dc chopper motor drive, cable losses are not considered.

(10.26) $DFM = EFM + ED2F + ID2\,(1/1.007 + 1/0.9766)/2000$ [VDC]

Equations (10.27) to (10.31) define motor performance:

DC MOTOR PERFORMANCE IN PULSATING DC POWER MODE

(10.27) $PAMOT = (EARM_{[AVG]} + DFM) \cdot IARM_{[AVG]}$ [WDC]

(10.28) $\eta AMOT = (PTR/PAMOT) \cdot 100$ [%]

(10.29) $PMOT = I^2\, ARM_{[RMS]}\, [(EARM + EFM)/IARM]_{[AVG]} + [ED2F \cdot ID2]_{[RMS]} +$
$I^2\; D2\, [(1/0.9766)^2 + (1/1.007)^2]/2000$ [WRMS]

(10.30) $\eta MOT = (PTR/PMOT) \cdot 100$ [%]

(10.31) $WLMOT = (PMOT - PTR)/TMOT)$ [WL/N-m]

CONTROLLER AND COMPONENT PERFORMANCE. Voltage and current vectors of the commutating circuit can normally be stored in a memory and then played back slowly to yield a Fourier analysis. In this instance the previously described wattmeter No. 2 was utilized to determine power loss in capacitor (C4). Equations (10.32) to (10.34) yield:

(10.32) $PLCOM = PLCTR - PTH1 - PD2 - PCT$ [WRMS]

(10.33) $PLAC4 = 100\, v_{o2[AVG]} \cdot (1.003/1.03)$ [WDC]

(10.34) $PLC4 = 100 \cdot v_{o2[RMS]} \cdot (1.003/1.03)$ [WRMS]

(10.35) $IC4 = v_{RSH8} \cdot 2000\ V/A \cdot K8$ [ARMS]

whereby:

$K8 = 1.003$, *shunt correction constant*

Equations (10.36) to (10.38) describe power loss in the controller:

(10.36) $PLCTR = PBAT - PMOT - P3$ [WRMS]

(10.37) $\eta CTR = (PMOT/PBAT) \cdot 100$ [%]

(10.38) $WLCTR = PCTR/TMOT$ [WL/N - M]

Approximate steady-state heat losses can be measured directly if a clamping circuit is incorporated which limits the forward voltage drop to 10 volts maximum. Equations (10.39) to (10.42) yield the forward conduction losses for thyristor TH1 (PTH1) and diode D2 (PD2F):

(10.39) $PATH1 = (ETH1 \cdot ITH1)_{[AVG]}$ [WDC]

(10.40) $PAD2F = ED2F \cdot (IARM - ITH1)_{[AVG]}$ [WDC]

$= (ED2F \cdot ID2)_{[AVG]}$

(10.41) $PTH1 = ETH1_{[RMS]} \cdot ITH1_{[RMS]}$ [WRMS]

(10.42A) $PD2F = ED2F_{[RMS]} \cdot \left[[(IARM - ITH1)_{[AVG]}/\sqrt{\Delta D2}] - IC4_{[RMS]} \right]$ [WRMS]

(10.42) $PD2F = ED2F_{[RMS]} \cdot ID2F_{[RMS]}$ [WRMS]

Thyristor TH1 transmits a reasonably well shaped rectangular current pulse. Heat losses can be determined by indirect means and as shown in equations (10.43) to (10.48):

(10.43) $VTH1 = (ETH1_{[AVG]}/\Delta MOT) \cdot \sqrt{\Delta MOT}$

$= ETH1_{[AVG]}/\sqrt{\Delta MOT}$ [VRMS]

(10.44) $ITH1 = ITH1_{[AVG]} \sqrt{\Delta MOT}$ [ARMS]

(10.45) $VD2F = ED2F_{[AVG]} / \sqrt{\Delta D2}$ [VRMS]

(10.46) $ID2F = (IARM - ITH1)_{[AVG]} / \sqrt{\Delta D2} - IC4$ [ARMS]

(10.47) $PTH1 = VTH1 \cdot ITH1_{[AVG]} / \sqrt{\Delta MOT}$ [WRMS]

(10.48) $PD2F = VD2F \cdot \left[[(IARM - ITH1)_{[AVG]} / \sqrt{\Delta D2}] - IC4_{[RMS]} \right]$ [WRMS]

Equation 10.49 yields the heat loss for the contactor.

(10.49) $PCT = IARM_{[RMS]} \cdot vCT_{[RMS]}$ [WRMS]

By definition, the measured battery current IBT′ includes the two current components IBAT′ and IAUX, whereby the former is the power current component and IAUX represents the control current component. However, for the purpose of this discussion, the control current component (IAUX) is neglected here. It should be noted that the "no load" battery voltage EBATO (VDC_{pk}) supplies the control current component (IAUX) continuously. This provides a realistic assessment of its open circuit terminal voltage. Under these conditions the voltage drop at the battery terminals is a function of the pulsed dc current load. The instantaneous power losses within the battery for this pulsed dc current load can then be calculated with equations (10.50) to (10.52):

(10.50) $\Delta EBAT_{[AVG]} = EBATO - EBAT_{[AVG]}$ [VDC]

(10.51) $PLABT = \Delta EBAT_{[AVG]} \cdot IBAT_{[AVG]}$ [WDC]

whereby the rate of depletion is considered constant.

Equation (10.52) yields the heat loss:

(10.52) $PLABT = I^2 BAT_{[RMS]} \cdot [\Delta EBAT/IBAT]_{[AVG]}$ [WRMS]

The in-circuit no load battery terminal voltage EBATO is defined by equation (10.53):

(10.53) $EBATO = \left[[(EBAT_1 - EBAT_2)/(IBAT_2 - IBAT_1)] \cdot IBAT_1 \right]_{[AVG]} + EBAT_{1\,(AVG)}$ (VDC)

whereby subscripts "1" and "2" denote column 1 and 2 of the raw data print out.

The system's equivalent dc power requirement (PAEV), power transfer efficiency (ηAEV) and watt loss/N-m (WLEV) under exclusion of the requirements for the controls is defined by equations 10.54 to 10.55:

$$\text{(10.54)} \quad PAEV = PABAT + PLABT \qquad \text{[WDC]}$$

$$\text{(10.55)} \quad \eta AEV = (PTR/PAEV) \cdot 100 \qquad [\%]$$

Equations (10.56) to (10.59) describe the power demand for the pulsating dc power operating mode:

$$\text{(10.56)} \quad PEV = PBAT + PLBAT \qquad \text{[WRMS]}$$

$$\text{(10.57)} \quad \eta EV = (PTR/PEV) \cdot 100 \qquad [\%]$$

$$\text{(10.58)} \quad WLEV = (PEV - PTR)/PTR \qquad \text{[WL/W]}$$

The generated heat loss is 10.59:

$$\text{(10.59)} \quad PHEAT = PLMOT + PLCTR \qquad \text{[WRMS]}$$

whereby:

$$PLMOT = PMOT - PTR \qquad \text{[WRMS]}$$

PERFORMANCE DEGRADATION. Degradation of motor and battery performance for the pulsating dc power operating mode is shown in equations (10.60) to (10.61):

MOTOR:

$$\text{(10.60)} \quad DEGM = 100\{\eta AMOT - \eta MOT\}/\eta AMOT \qquad [\%]$$

BATTERY:

$$\text{(10.61)} \quad DEGEV = 100[\eta AEV - \eta EV]\eta AEV \qquad [\%]$$

6. EVA Propulsion System

The total performance of the EVA Metro Sedan propulsion system is described in equations (10.62) to (10.66):

$$\text{(10.62A)} \quad PEVA = PO/\eta EVA \qquad \text{(WRMS)}$$

$$\text{(10.62B)} \quad PEVA = PBAT + PLBAT \qquad \text{(WRMS)}$$

$$\text{(10.63)} \quad \eta EVA = \eta EV \cdot \eta TR \qquad (\%)$$

$$\text{(10.64)} \quad WLEVA = (PEVA - PO)/PO \qquad \text{(WL/W)}$$

$$= (1/\eta EVA) - 1 \qquad \text{(WL/W)}$$

WHEEL SPEED:

$$\text{(10.65)} \quad v_{EVA} = \frac{NTR - (60 \cdot SL \cdot GR)}{GR} \cdot 2\pi \cdot 0.92 \cdot 12 \cdot 2.54 \cdot 60 \cdot 10^{-5} \qquad \text{(Km/h)}$$

REQUIRED VEHICLE ENERGY:

$$(10.66)\quad DEVA = (PTR_{HP} \cdot 745.7_W \cdot 10^{-3} \frac{NTR^x}{2500} \cdot WLEVA \frac{WL}{W} / V_{EVA} \qquad (KWH/KM)$$

x $\quad NTR > 2500 \rightarrow (NTR/2500) \rightarrow 1$

$\quad\quad\quad < 2500 \rightarrow (NTR/2500) \rightarrow$ as stated

7. **Measurement of In-Circuit Inductance**

Although beyond the scope of this investigation, a reasonable facsimile of the impulse voltage across the series field during the forward conduction period of thyristor TH1 is attainable with the aid of a forward voltage clamp, similar as shown in Figure 9.12. The standard expression for the definition of induction $e_L = L\, di/dt$ is expanded to yield the expression for the in-circuit field inductance as shown in equation (10.67):

$$(10.67)\quad LFM = \left[\left[[(EFM)^2{}_{RMS} - (IFM_{RMS}(EFM/IFM)_{AVG})^2\ ]/\Delta MOT \right]^{1/2} \cdot \Delta t \right] / \Delta ITH1 \Bigg|_{t=tc}^{t=0}$$

whereby:

$$\Delta t = MOT \cdot fc$$

The time interval (Δt) as well as the current interval (ITH1) are directly measurable with the HP SVMBP program routing (Ref. 6).

XI. TRANSMISSION TEST

Data points for the mechanical transmission were obtained in the constant input torque mode, whereby the input speed (NTR) was the controlled variable and output speed (NO) was a measured quantity. Figures 11.1 through 11.6 illustrate transmission performance for first, second and third gear operation. The underutilized transmission, originally designed for a 75 HP power plant, is mismatched for this application and generates an excessive power loss per unit torque applied to the wheels. The applied input torque (TMOT) on the first gear had to be restricted to 41 Newton-meter (N-m) in order not to exceed the drive shaft sensor's torque rating TO = 340 N-m.

The entire EVA transmission test routine, including the software and the parametric data print-out is shown in Appendix B. The transmission test nomenclature is shown in Table B1.

XII. DC MOTOR TEST

1. **DC Motor Performance.** Motor performance was evaluated initially with the aid of conventional instrumentation for general reference. Motor power loss and performance curves were plotted according to conventional practice and are shown in Figures 12.1 to 12.10. Table 8 and Figure 12.3 provide windage, friction and magnetic loss information; Table 9 and Figure 12.4 identify windage and friction losses of the machine. Table 10 shows the rotor inertia for the propulsion motor.

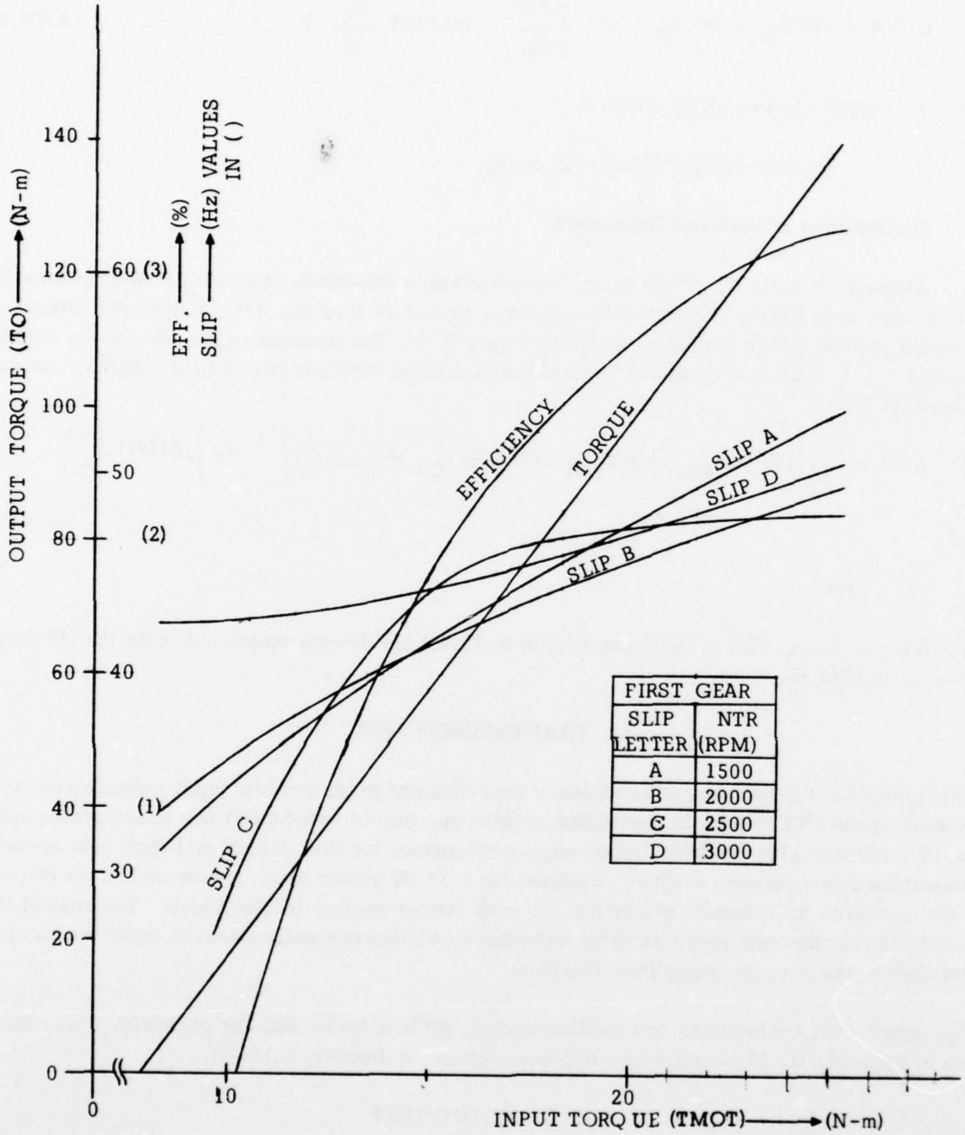


FIGURE 11.1: TRANSMISSION PERFORMANCE TEST IN FIRST GEAR (GR1)

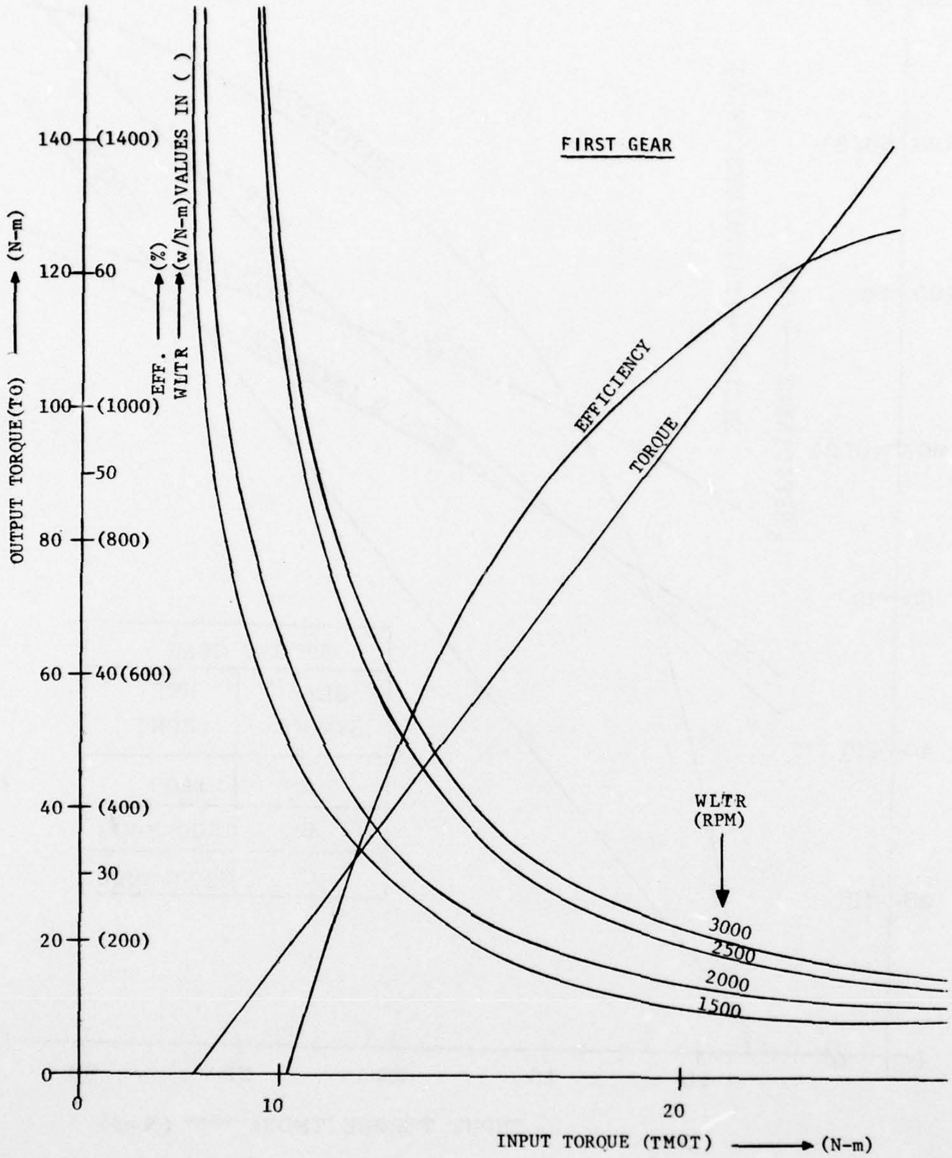


FIGURE 11.2: TRANSMISSION PERFORMANCE
TEST IN FIRST GEAR (GR1)

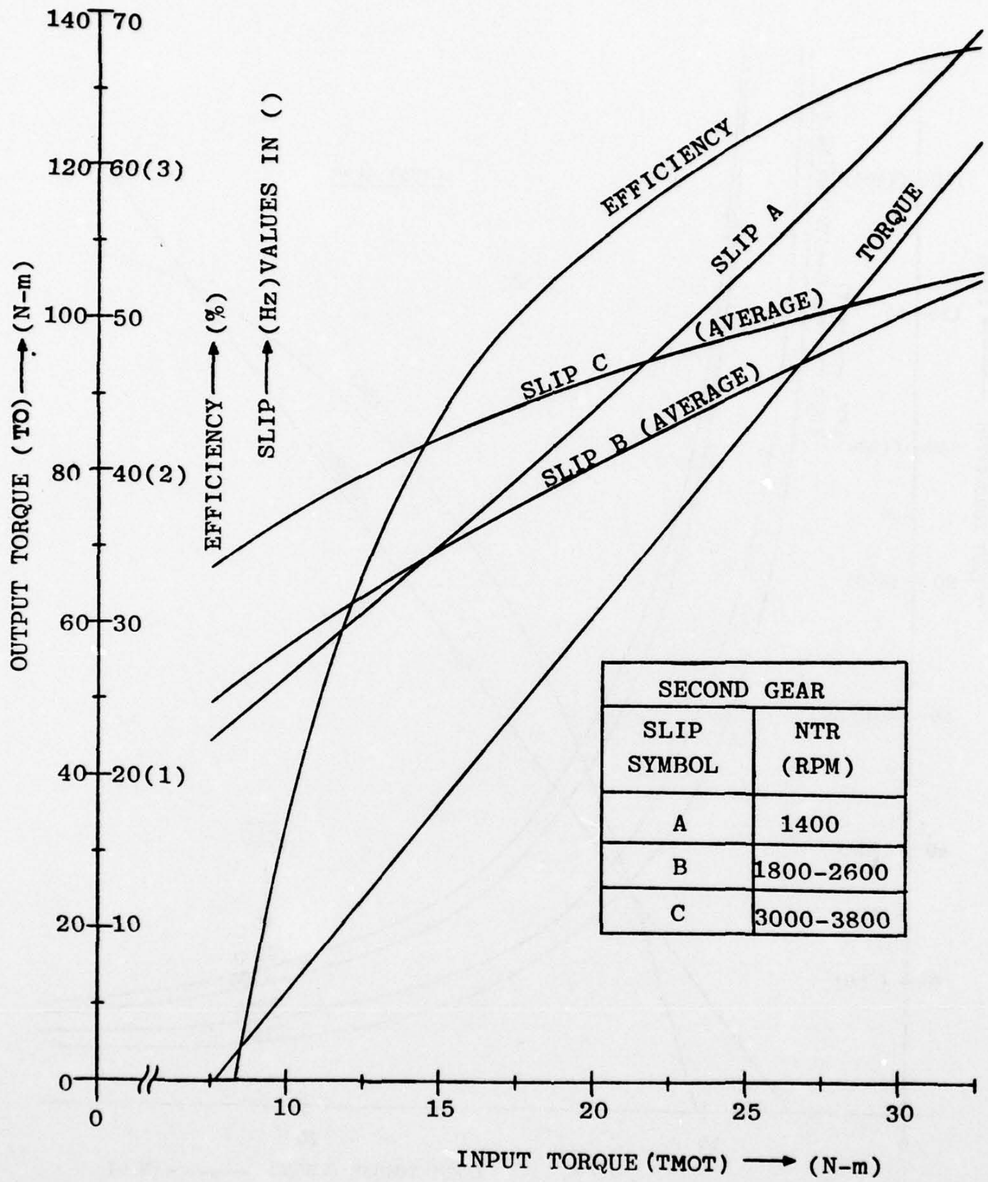


Figure 11.3. Transmission test performance in second gear (GR2).

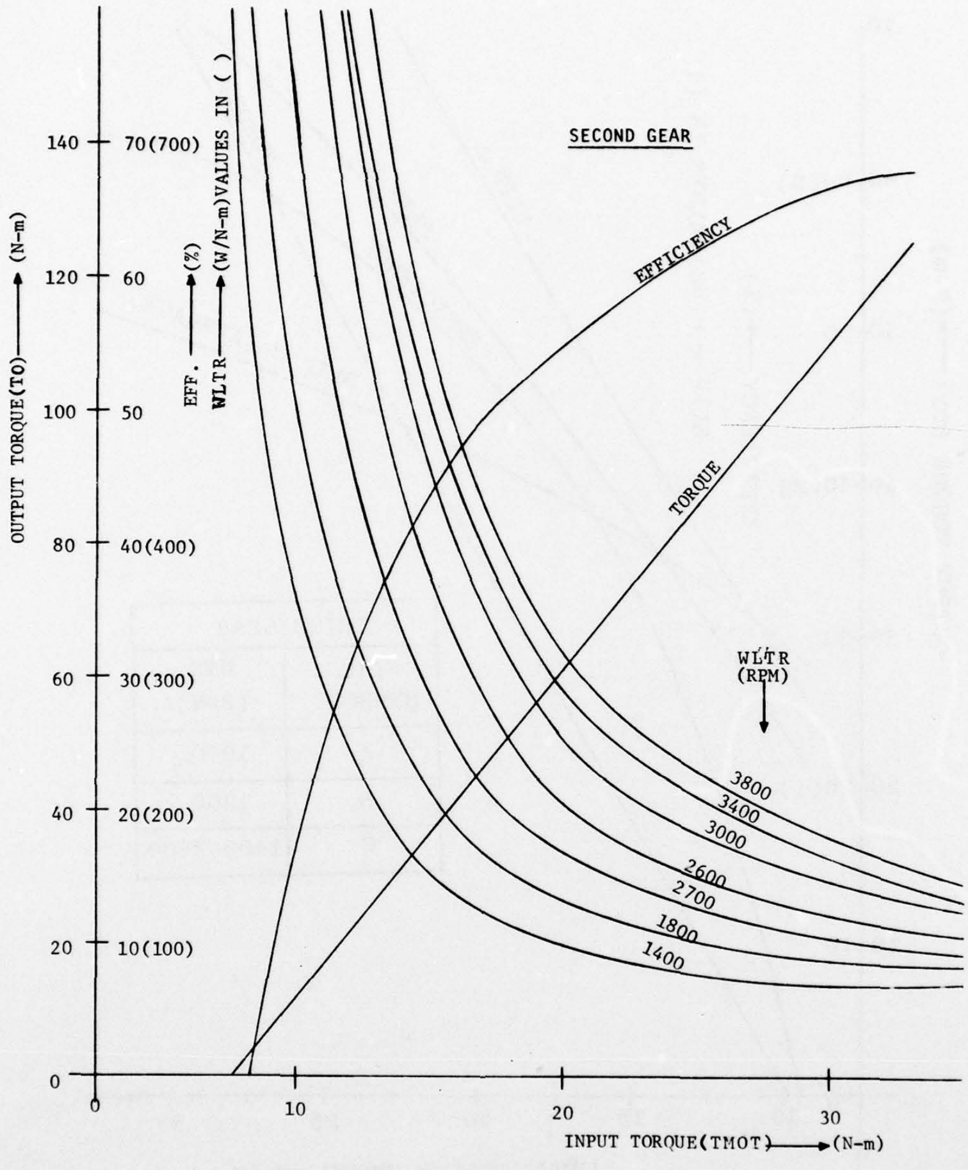
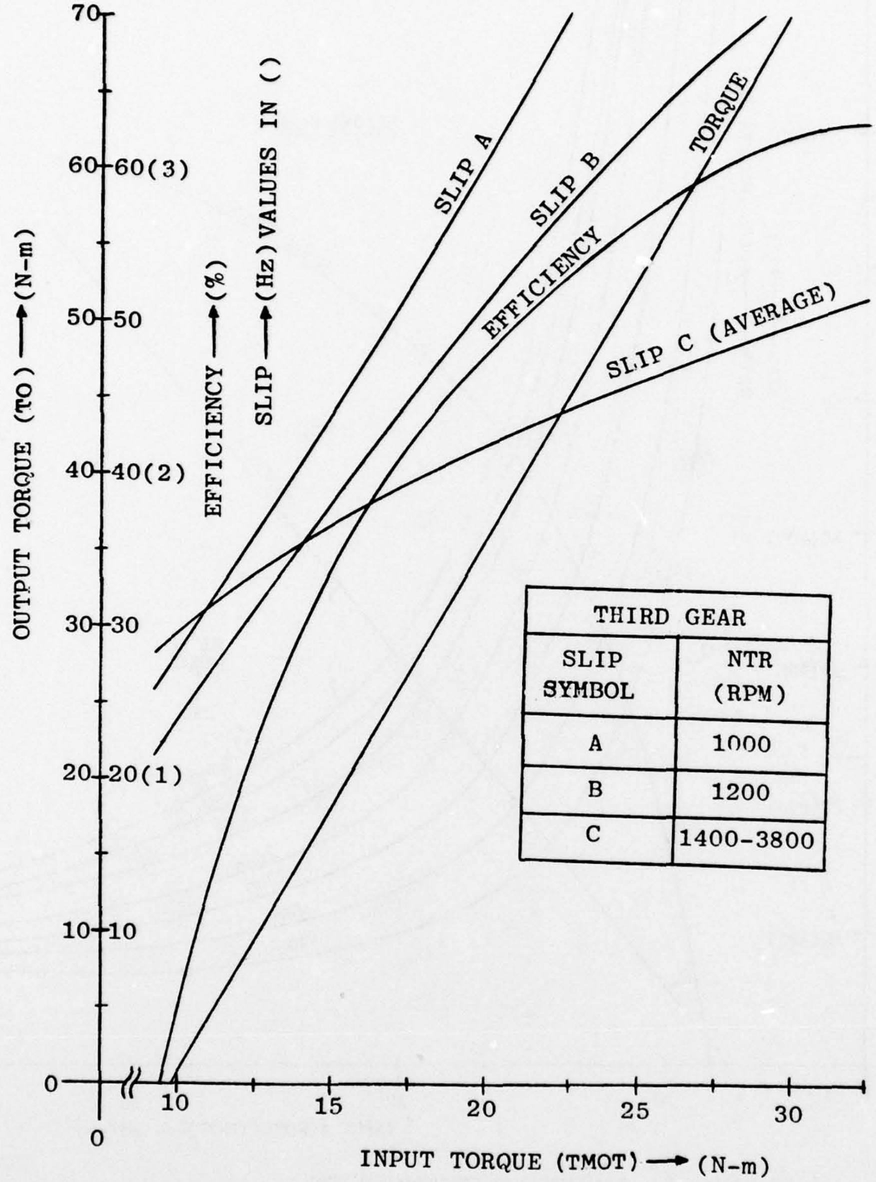


FIGURE 11.4: TRANSMISSION PERFORMANCE TEST
IN SECOND GEAR (GR2)



THIRD GEAR	
SLIP SYMBOL	NTR (RPM)
A	1000
B	1200
C	1400-3800

Figure 11.5. Transmission performance test in third gear (GR3).

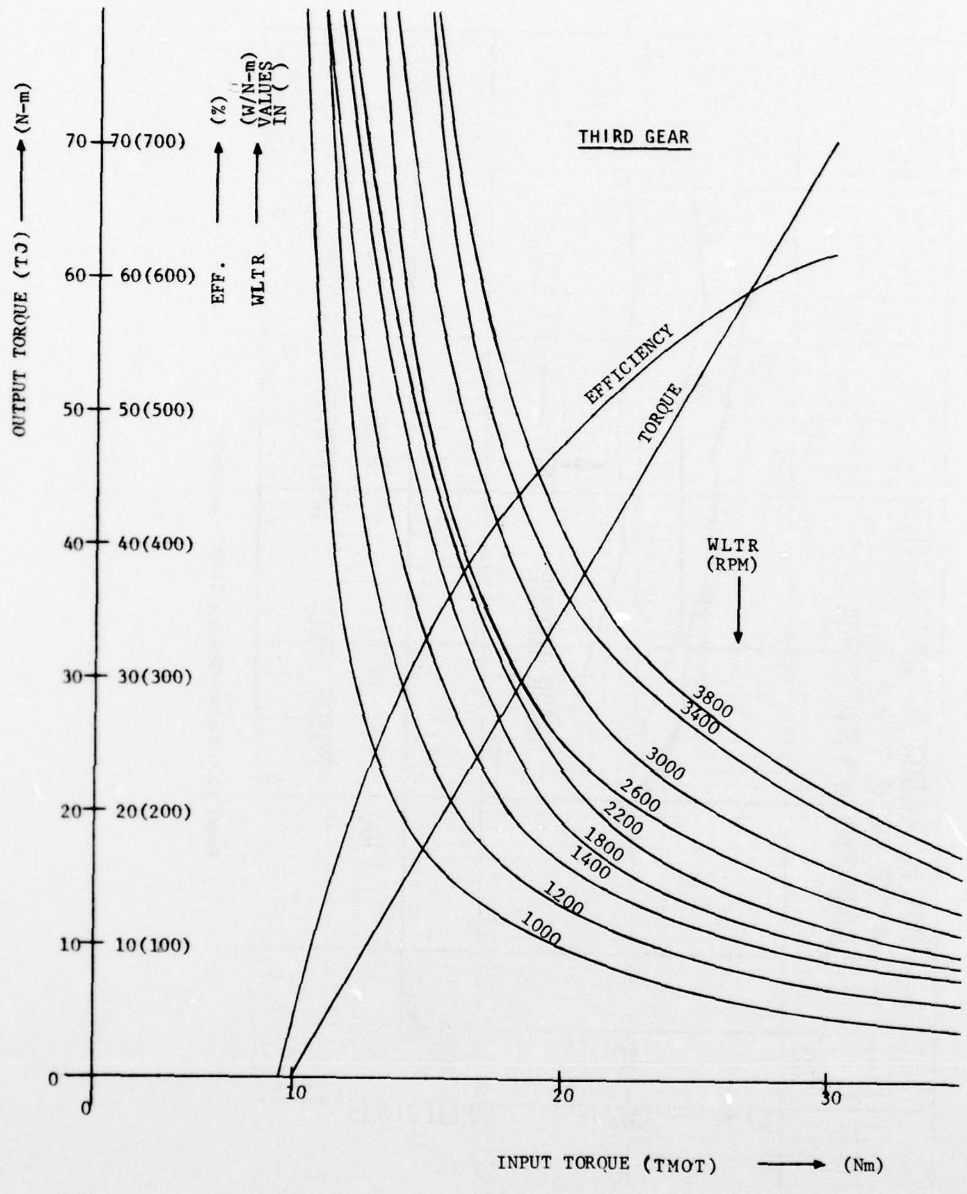


FIGURE 11.6: TRANSMISSION PERFORMANCE TEST IN THIRD GEAR (GR3)

XII-1. MOTOR PERFORMANCE TEST.

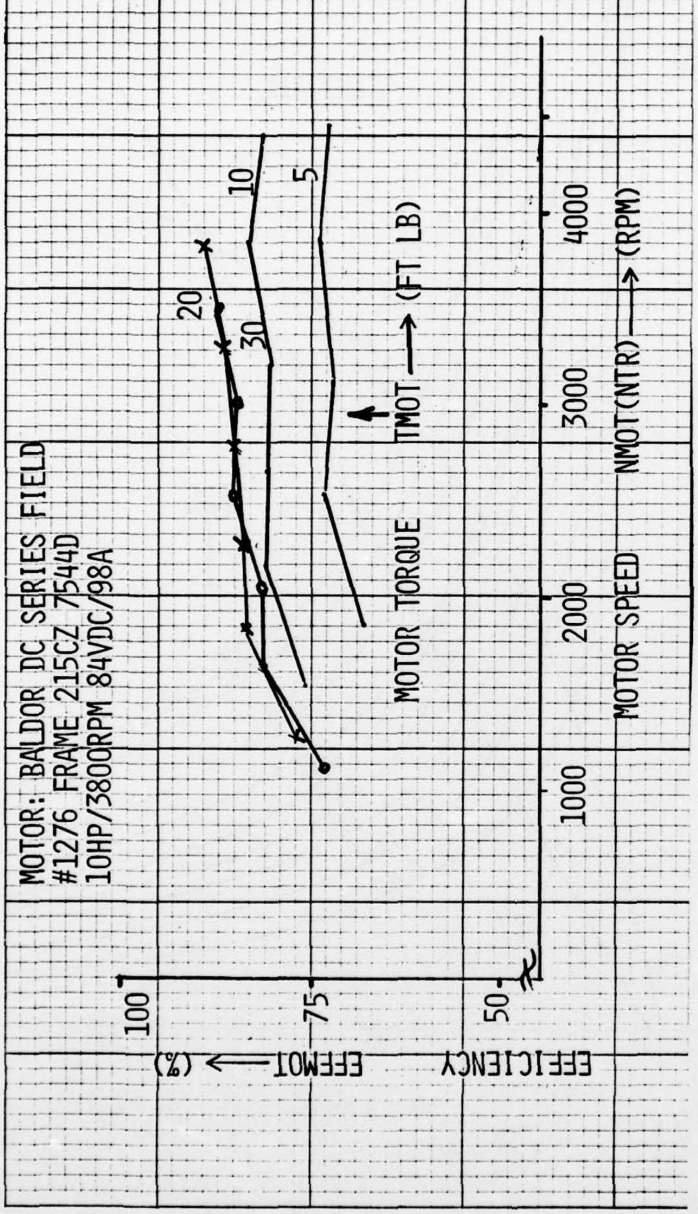


Figure 12.1. Motor efficiency, TMOT = parameter.

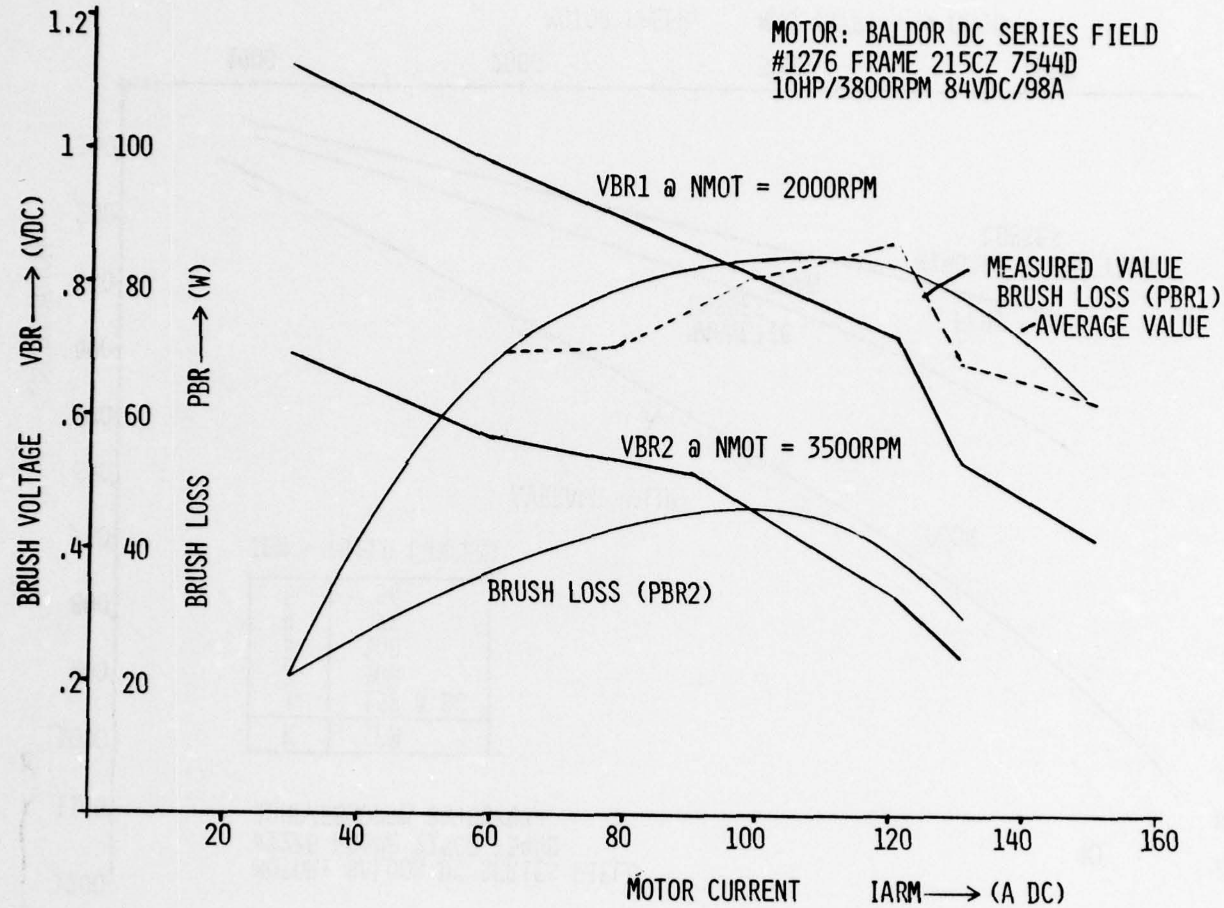


Figure 12.2. Brush losses vs. motor current.

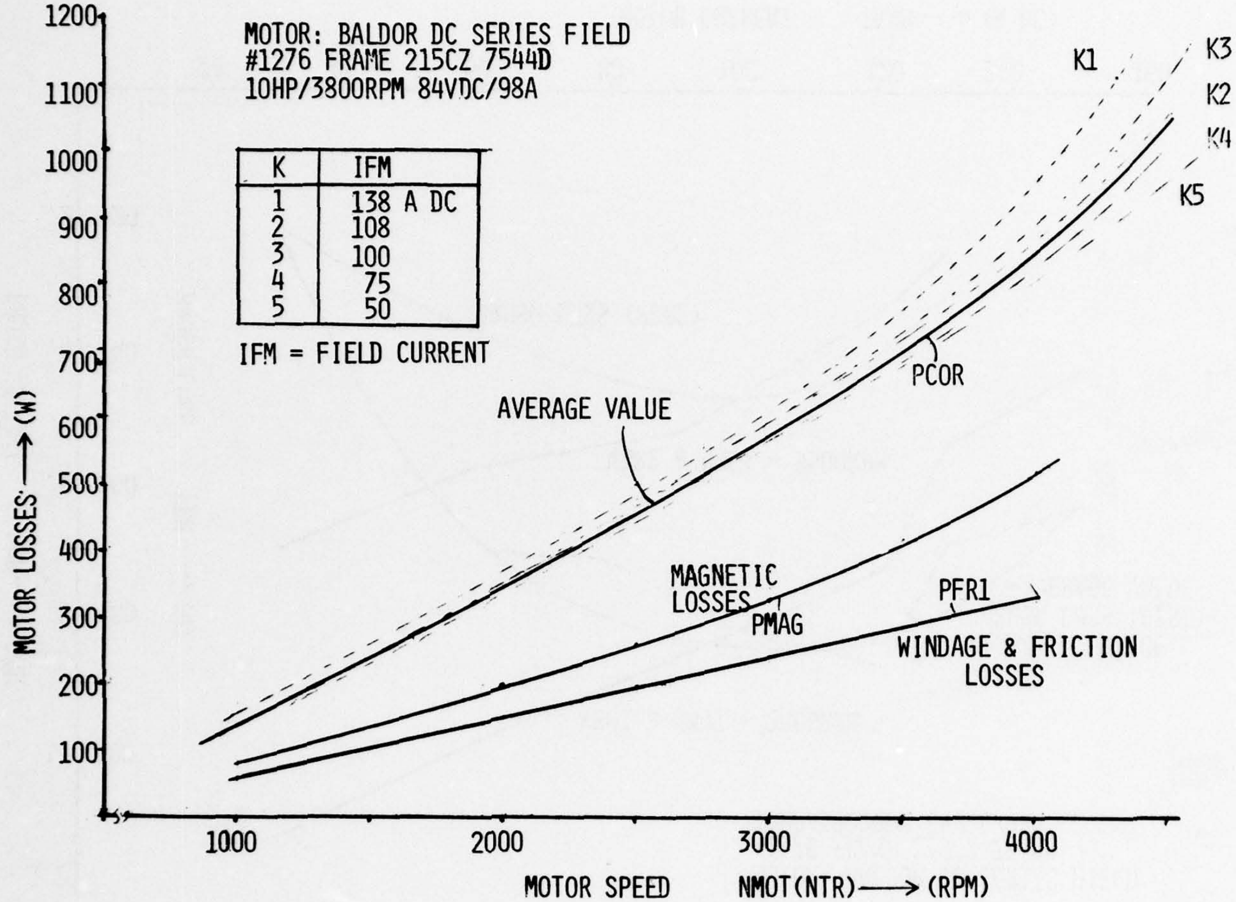


Figure 12.3. Windage, friction and magnetic loss.

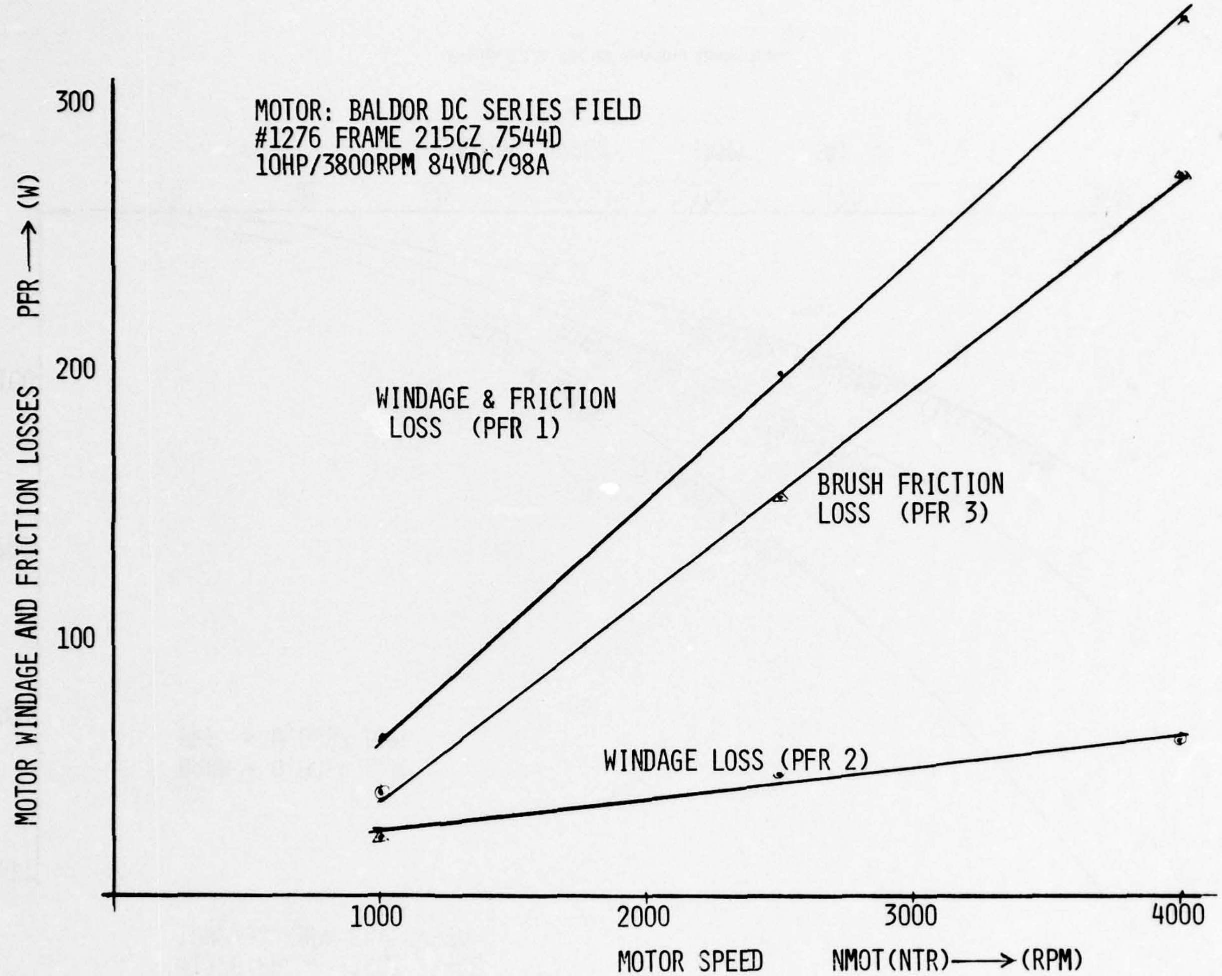


Figure 12.4. Windage and friction loss.

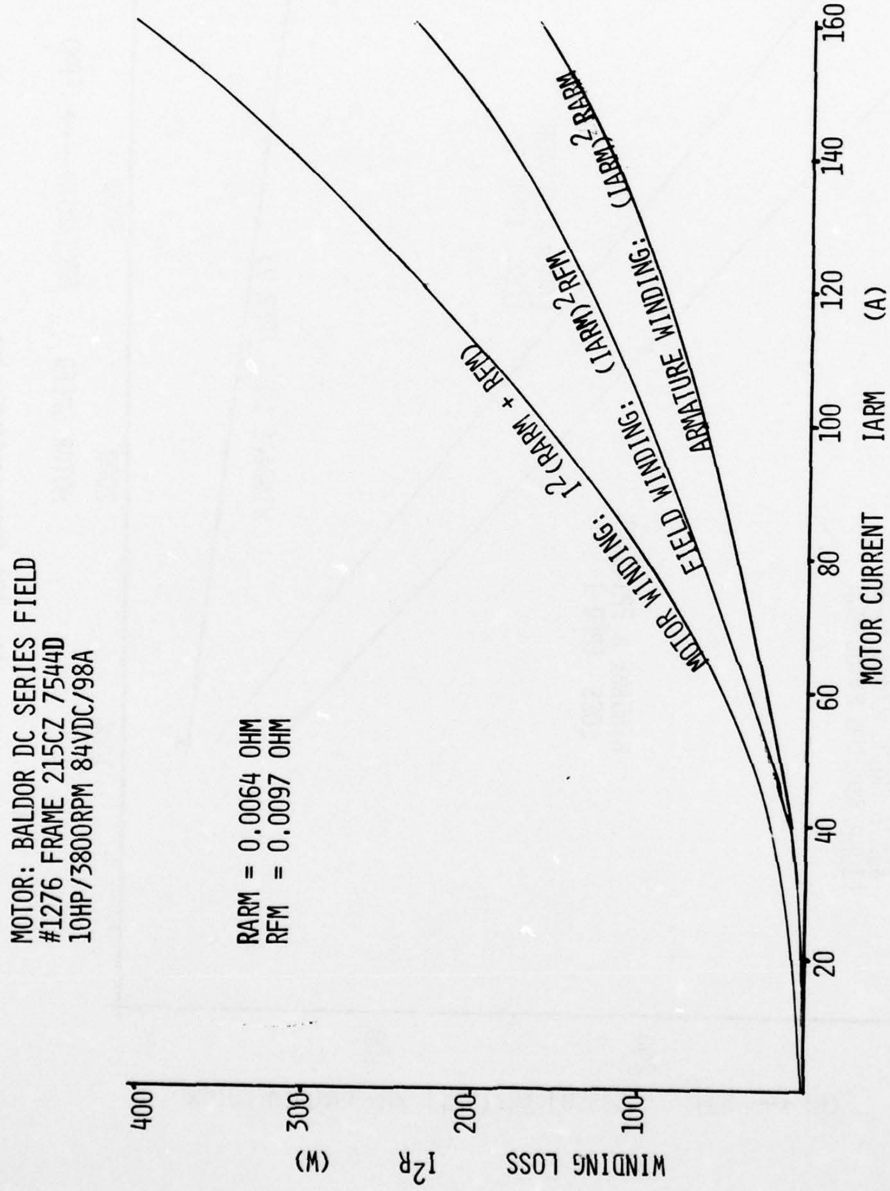


Figure 12.5. Motor winding dissipation.

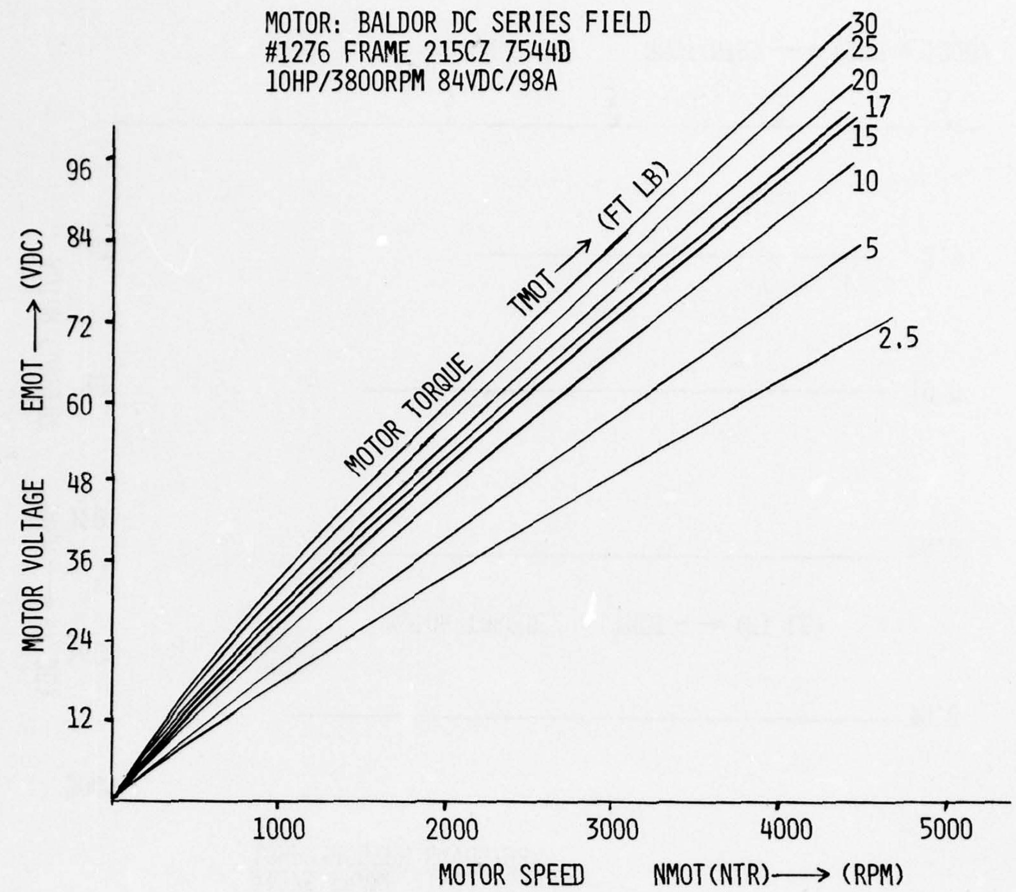


Figure 12.6. Motor voltage vs. motor speed.

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EVA METRO SEDAN ELECTRIC PROPULSION SYSTEM TEST AND EVALUATION.(U)
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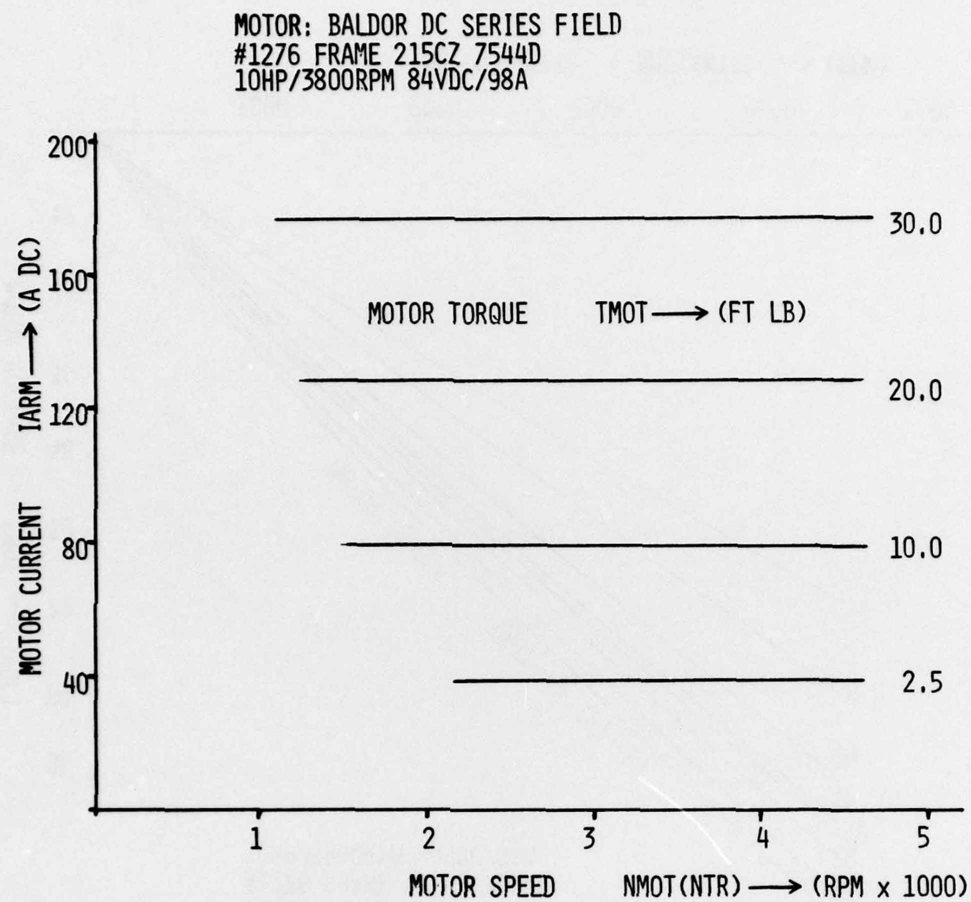


Figure 12.7. Motor current vs. speed.

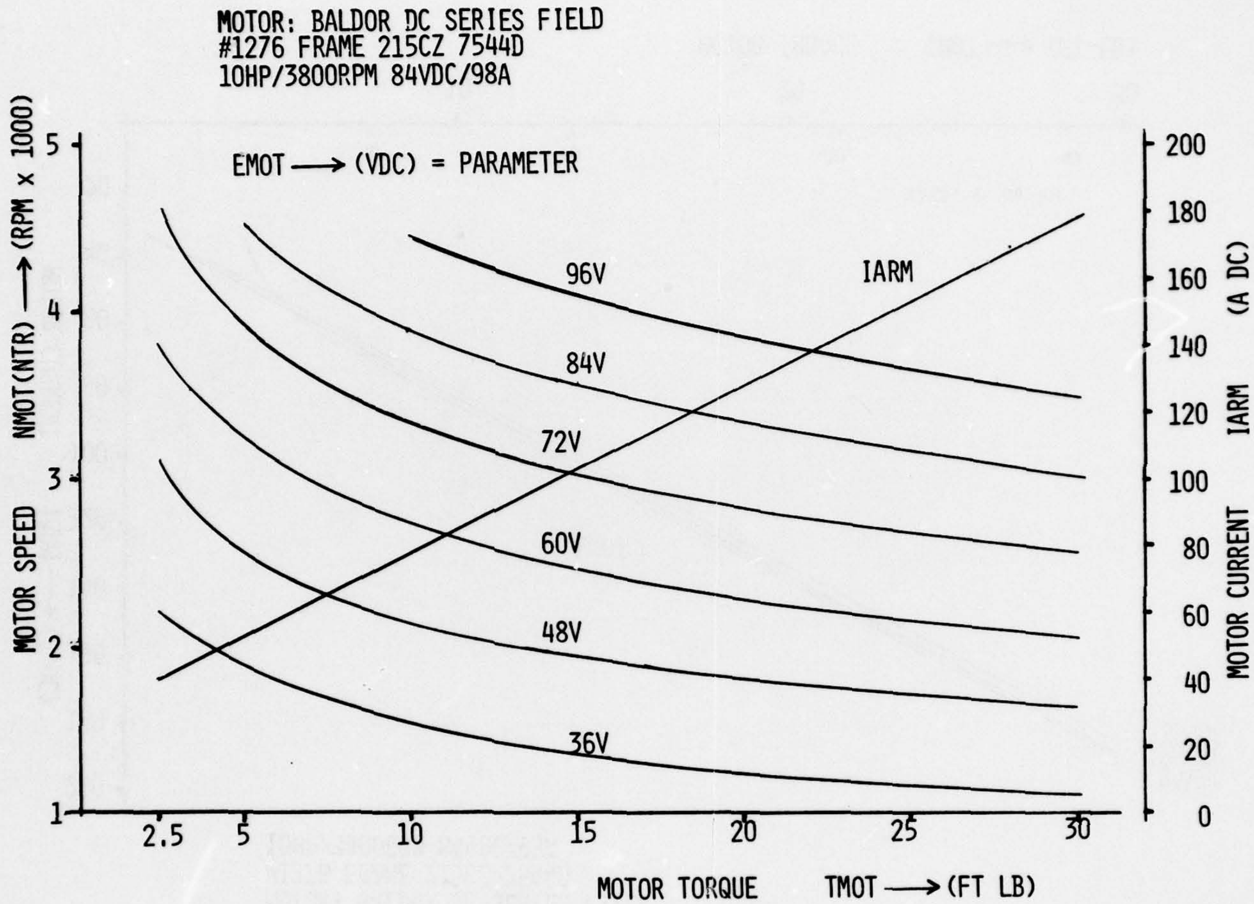


Figure 12.8. Motor torque vs. current and speed.

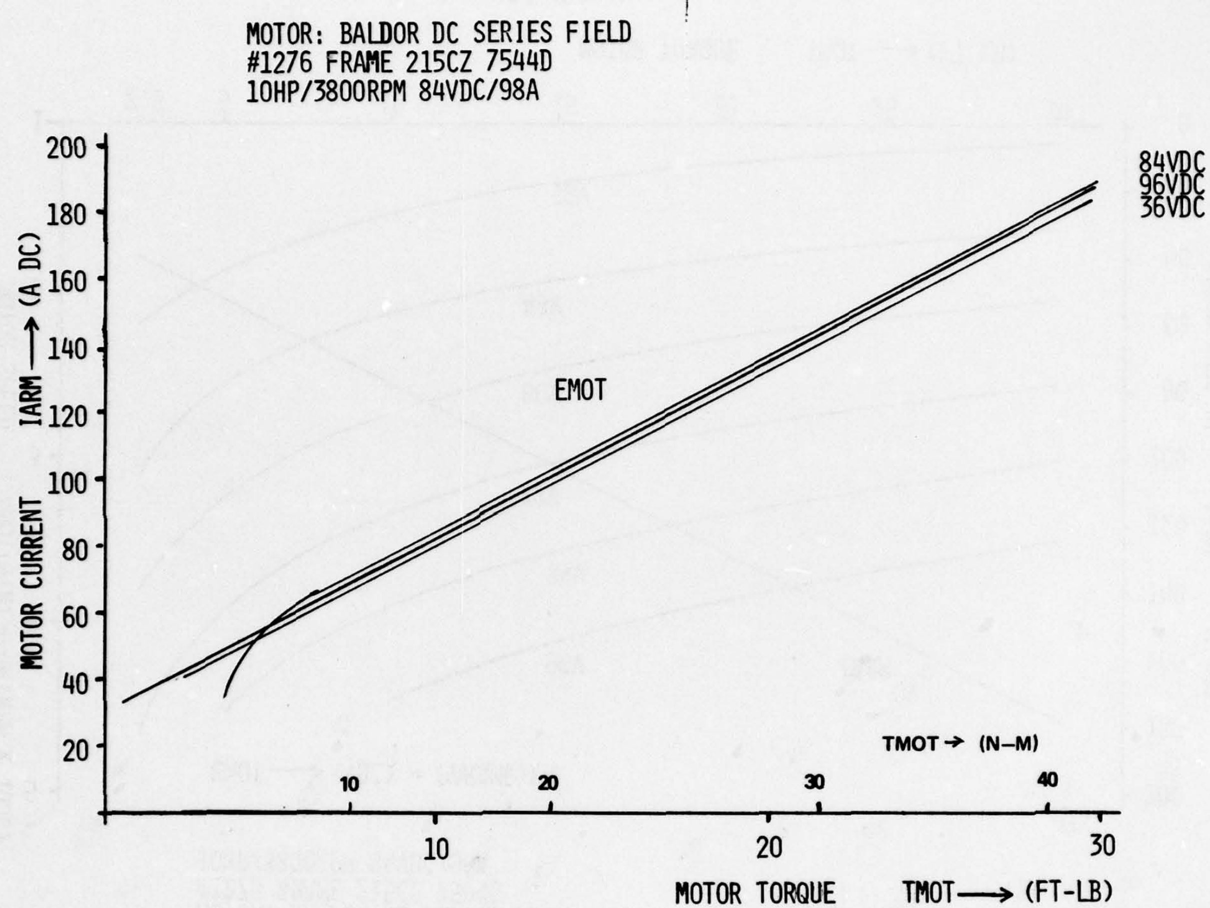


Figure 12.9. Motor current vs. motor shaft torque.

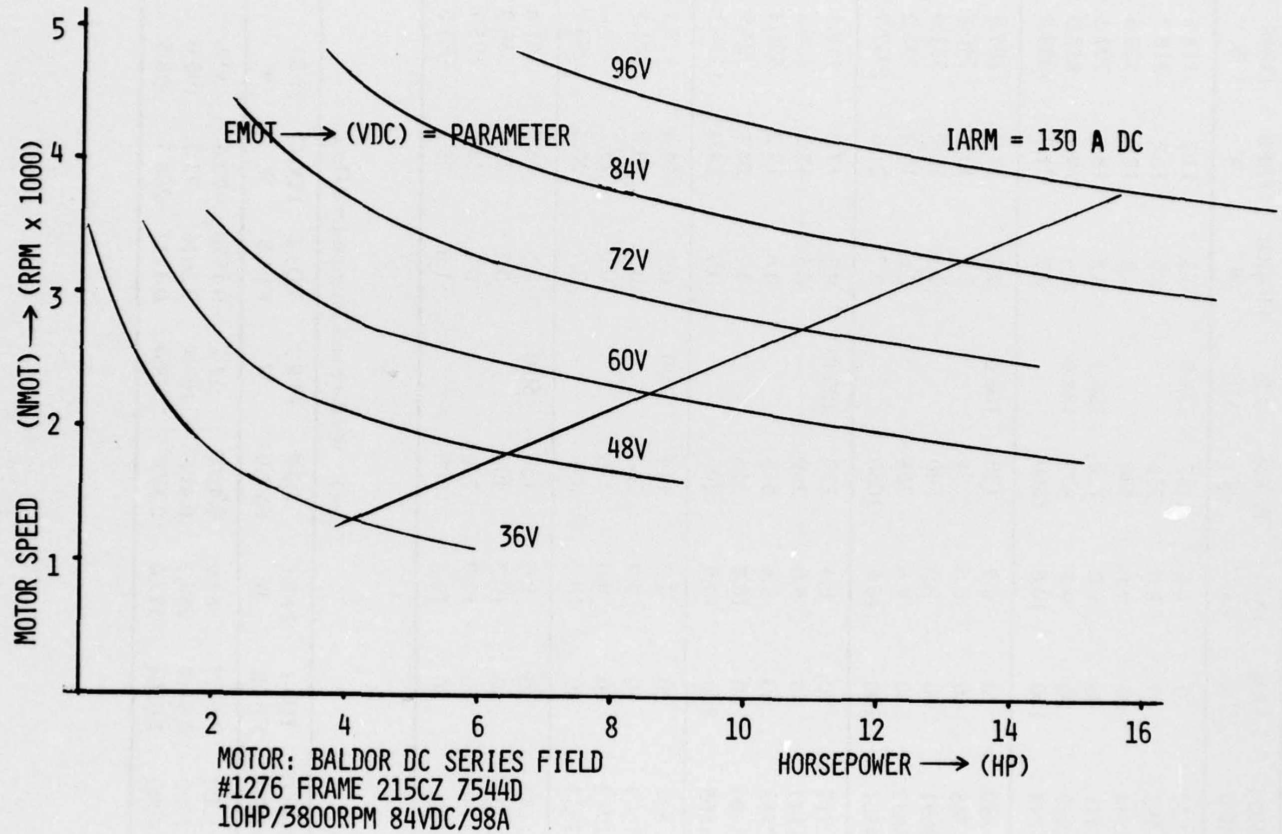


Figure 12.10. Motor speed vs. shaft power.

Table 8: Windage, Friction and Magnetic Loss Data

NMOT RPM	EARM VDC	IARM ADC	PARM W	IFM ADC	PRARM W	PBRS W	PCOR W	Designation
820	20	6.6	132	136.8	0.3	13.2	118.5	
1683	40	8.4	336		0.5	16.8	318.7	K1
2544	60	9.0	540		0.5	18.0	521.5	
3431	80	9.0	720	136.1	0.5	18.0	701.5	
3839	90	9.7	873	138.0	0.6	19.4	853.0	
4294	100	10.6	1060		0.7	21.2	1038.8	
850	20	6.0	120	108.0	0.2	12.0	107.8	
1765	40	6.6	254		0.3	13.2	240.5	K2
2691	60	9.0	540		0.5	18.0	521.5	
3632	80	9.6	768		0.6	19.2	748.2	
4501	100	10.8	1080		0.7	21.6	1057.7	
917	20	6.6	132	100.0	0.3	13.2	118.5	
1147	40	9.0	360		0.5	18.0	336.6	K3
2758	60	9.6	576		0.6	19.2	556.2	
3700	80	10.2	816		0.7	20.4	794.9	
4565	100	12.0	1200		0.9	24.0	1175.1	
927	20	7.2	144	75.0	0.3	14.4	129.3	
1939	40	9.0	360		0.5	18.0	341.5	K4
2942	60	9.6	576		0.6	19.2	556.2	
3933	80	10.2	816		0.7	20.4	794.9	
1133	20	9.0	180	50.0	0.5	18.0	161.5	
2275	40	10.2	408		0.7	20.4	386.9	K5
3436	60	12.0	720		0.9	24.0	695.1	
4620	80	12.6	1008		1.0	25.2	981.8	

Table 9: Windage and Friction Loss Data

NMOT RPM	TQ3-1 FT-LB	PFR1' W	TQ3-2 FT-LB	PFR2' W	TQ3-3 FT-LB	PQ03 W	PFR1 W	PFR2 W	PFR3 W
1000	0.5777	82.0	0.4202	59.7	0.1576	22.4	59.6	37.3	22.3
2500	0.8119	288.2	0.4727	167.8	0.2626	93.2	195.0	45.8	149.2
4000	1.0504	597.0	0.5777	328.0	0.4727	268.5	328.5	59.5	269.0

TABLE 10: ROTOR INERTIA FOR
EVA #1 METRO SEDAN PROPULSION MOTOR

A. MEASURED DATA		W/LB	A INCHES	L INCHES	T SEC/CYCLE
ROTOR WITH END BELL	(J1)	62	9.25	116.75	1.87
END BELL ALONE	(J2)	16.8	10	116.25	2.64

B. INERTIA DATA	FT LBS^2	$MKGS^2$
J_1	.335398	
J_2	.212610	
J_M (ROTOR)	.122788	$130.89 \cdot 10^{-6}$

The nomenclature for Tables 8 and 9 and Figures 12.2 to 12.5 is:

PCOR	Motor Windage, Friction (Bearing and Brush Friction) and Magnetic Losses	W
PFR1	Windage and Friction Losses	W
PFR2	Windage (Including Bearing) Loss	W
PFR3	Brush Friction Loss	W
PMAG	Watt-Loss in Magnetic Structure	W
PBR	Electric Power Loss in Brushes	W
PRARM	$(IARM)^2$ RARM Power Loss in Armature Winding	W
PRFM	$(IARM)^2$ RFM Power Loss in Series Field Winding	W
RARM	Armature Winding Resistance	W
RFM	Field Winding Resistance	W

2. **Parametric Test Data.** Figures 12.11 to 12.13A-I illustrate motor performance as measured with the HP 3052A Data Acquisition System. The performance curves shown in Figures 12.11 and 12.12 were obtained from the constant speed, variable torque curves of Figures 12.13A-I and from the parametric data print-out. Software and data for the parametric test program are shown in Appendix C. Both sets of data track each other within typically 2%. However, manual data took typically 30 minutes/speed point, while automated data tracking took typically 20 sec/speed point at a considerably higher resolution.

The motor is rated at PMOT1 = 10KW @ 4000 RPM. The constant power rating of the machine was extended to 2000 RPM at which speed the current in the motor is two times the current amplitude at 4000 RPM. The other power envelopes, namely PMOT2; PMOT3; PMOT4; and PMOT5 represent 0.75; 0.5; 0.25; and 1.25 PMOT1 motor power ratings, whereby the low corner frequency is based on two times the current value for PMOT1 @ 4000 RPM.

XIII. DC CHOPPER MOTOR DRIVE TEST

In this test sequence system performance, component utilization and the performance degradation of battery and motor performance when operated in the pulsating dc power mode was investigated. The software, shown in Appendix C, was generated to enable the parametric testing of motor and system for both the unbuffered battery and buffered battery operation. Because of inadequate instrumentation, due to noise and inability to store analogously the open circuit battery voltage [EBATO] for the duration of the test, the direct measurement of losses in the battery (PLABT, PLBAT) and commutating circuit (PACOM, PCOM) led to misleading data. Hence, the measured data were replaced with calculated data. It is noteworthy that the measurement of either AVG or RMS quantities is performed by the HP 3455A Digital Voltmeter over several cycles of operation. Inasmuch as current and voltage vectors are approximately in phase in this type dc chopper circuit, power can be calculated by simple multiplication. Voltage vectors across power semiconductor devices (TH1) and (D2) were clamped to 10-volt maximum aplitude with the aid of adaptor circuits to remain within the HP 3445A crest factor specification of 8:1. This also simplified software when logging power dissipation of either device during either device's forward conduction mode.

XII-2. PARAMETRIC TEST DATA.

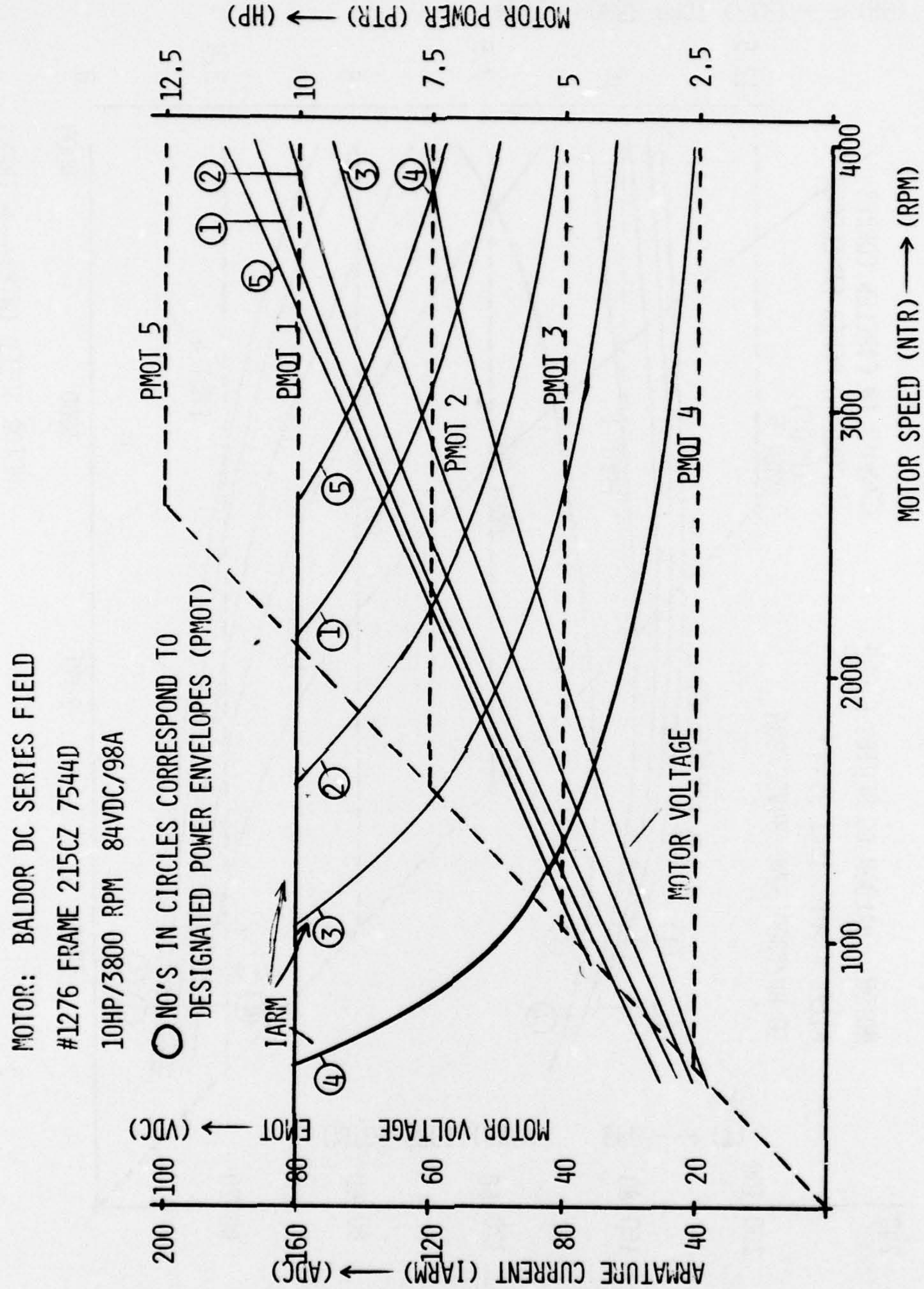


Figure 12.11. Parametric test data, motor current and voltage.

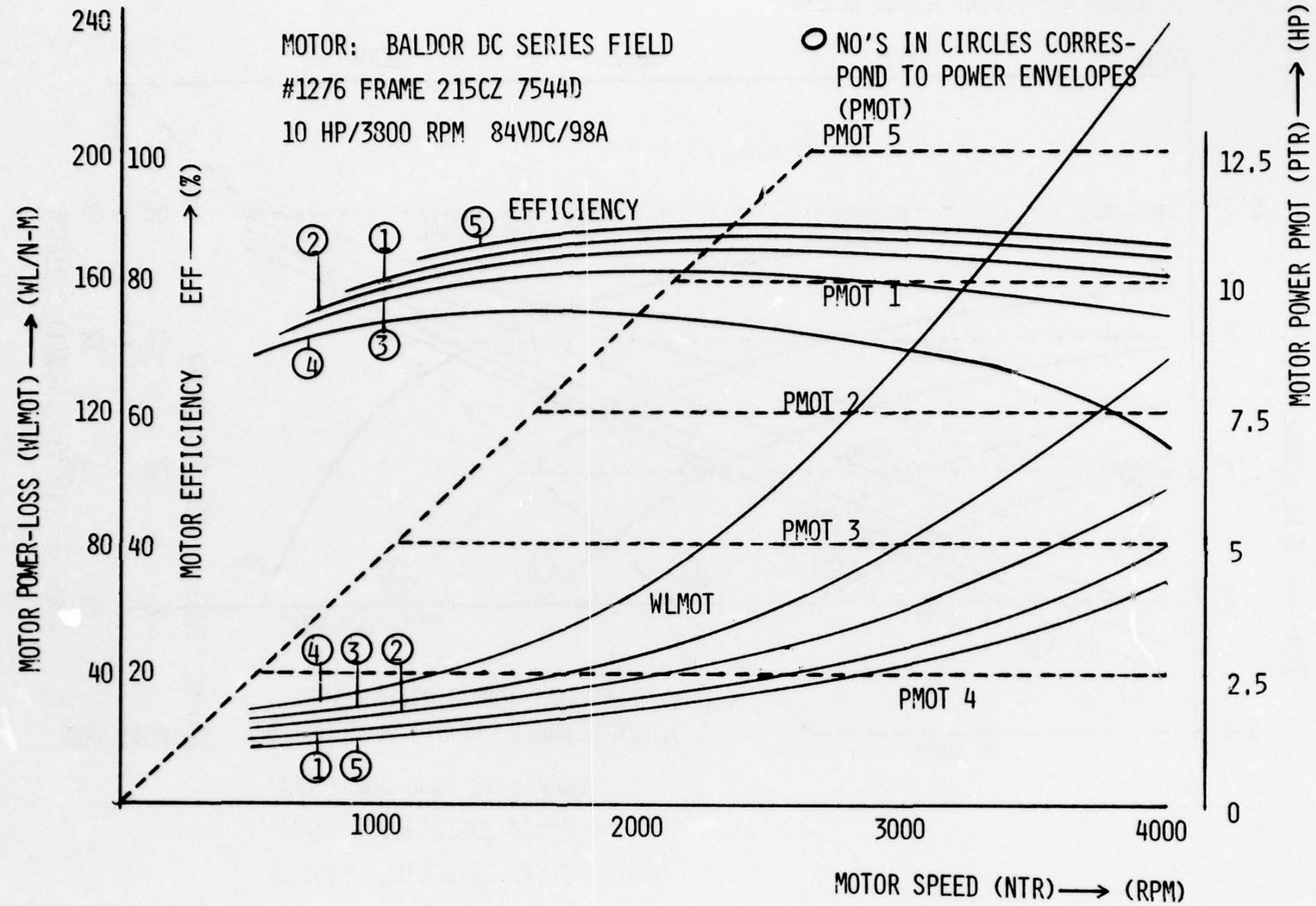


Figure 12.12. Parametric test data, motor efficiency and power loss per unit torque.

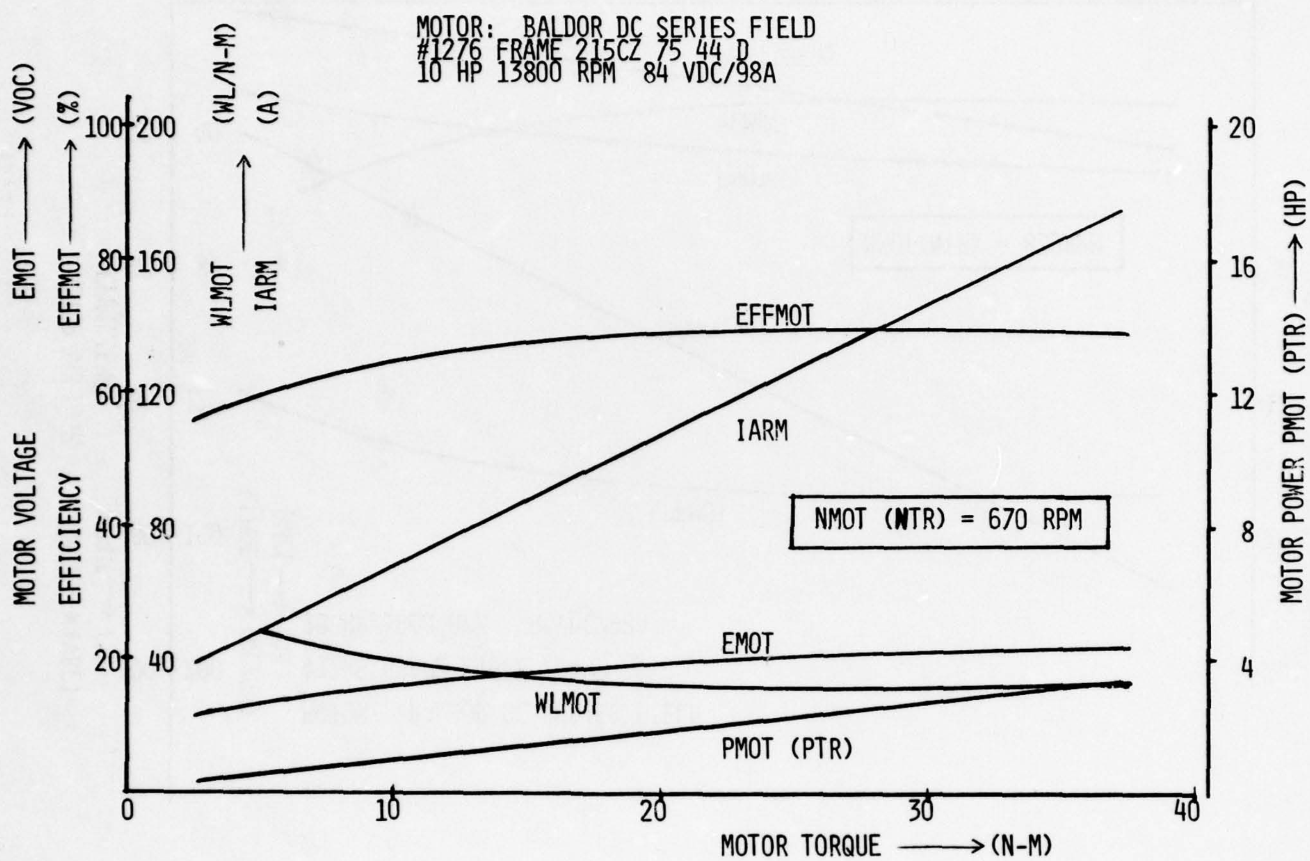
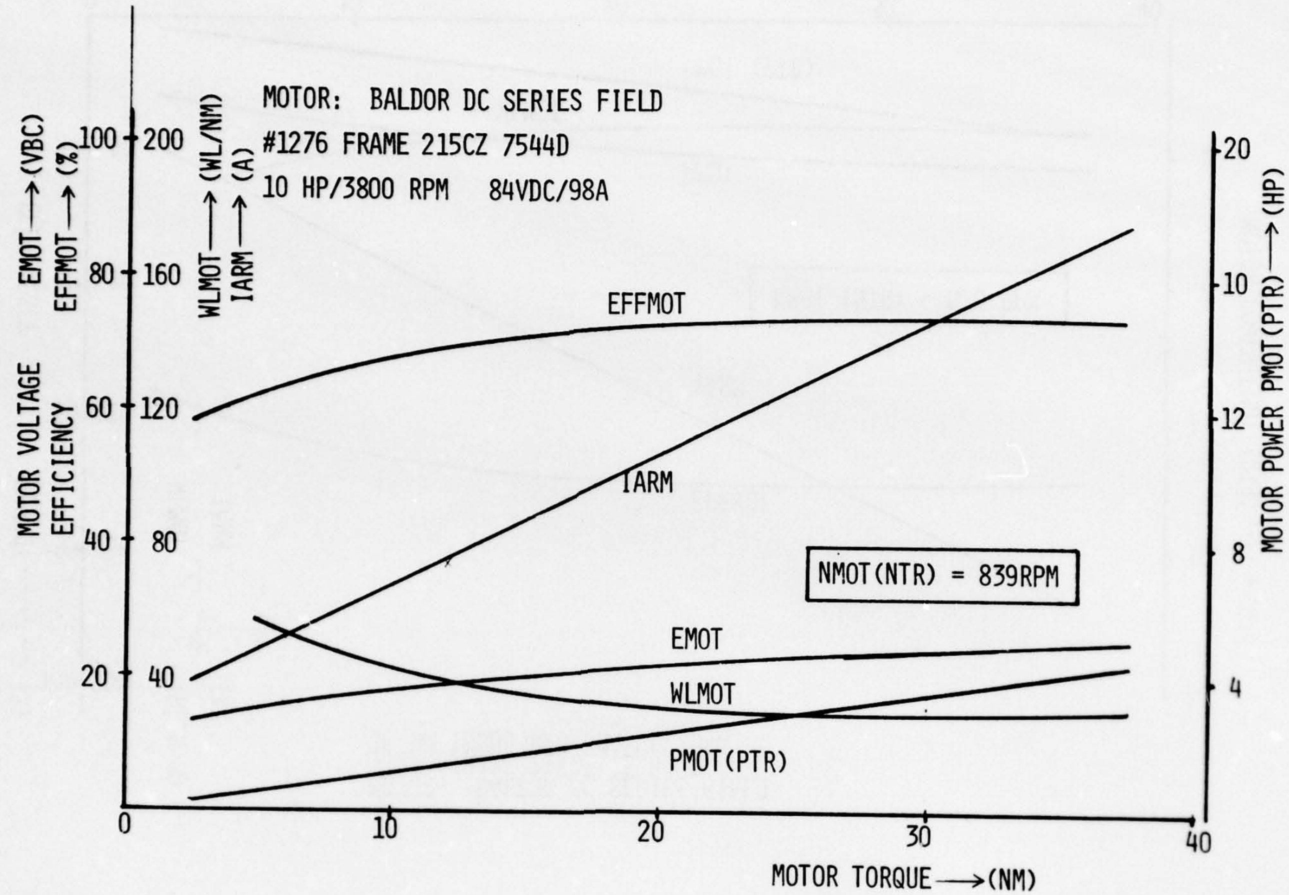


Figure 12.13A. Parametric test data @ NMOT = 670 RPM.



12.13B. Parametric test data @ NMOT = 839 RPM.

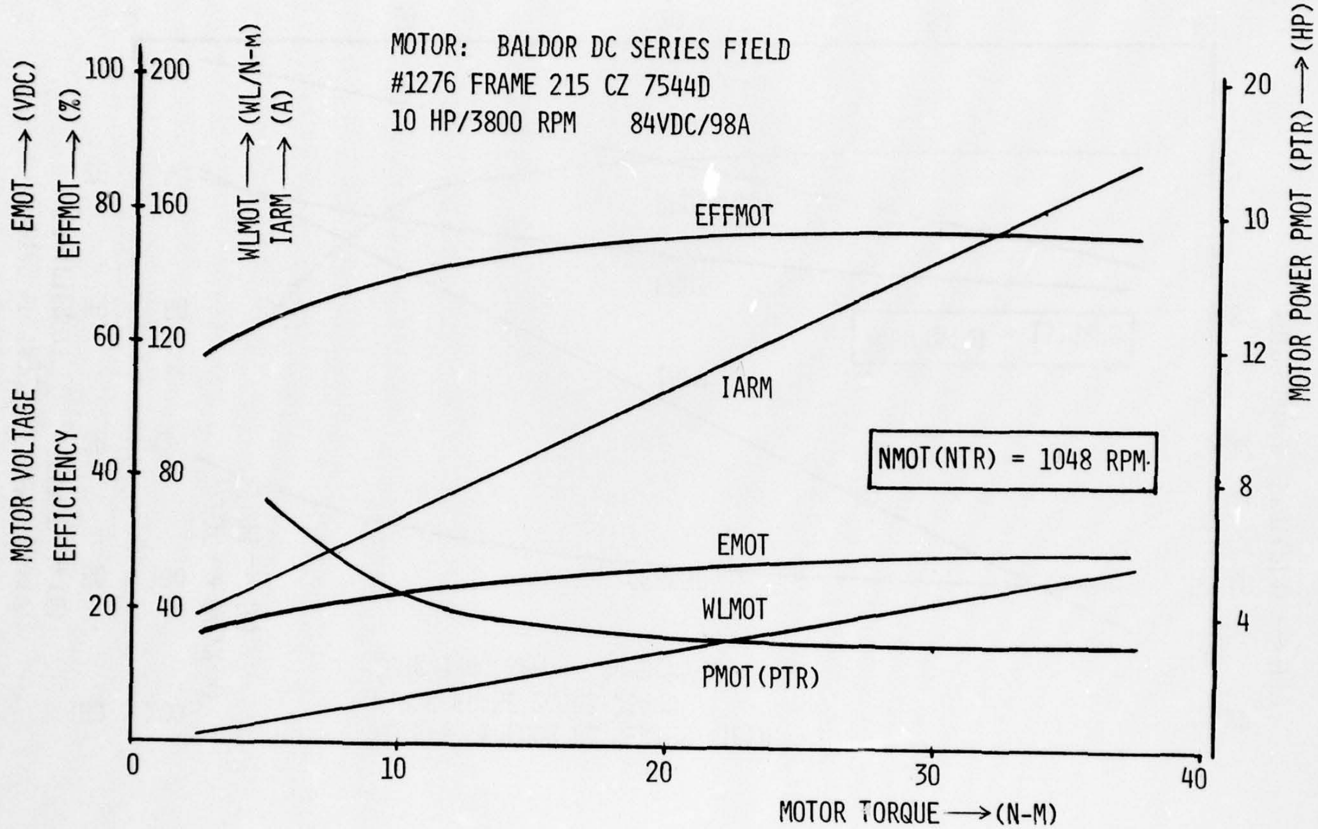


Figure 12.13C. Parametric test data @ NMOT = 1048 RPM.

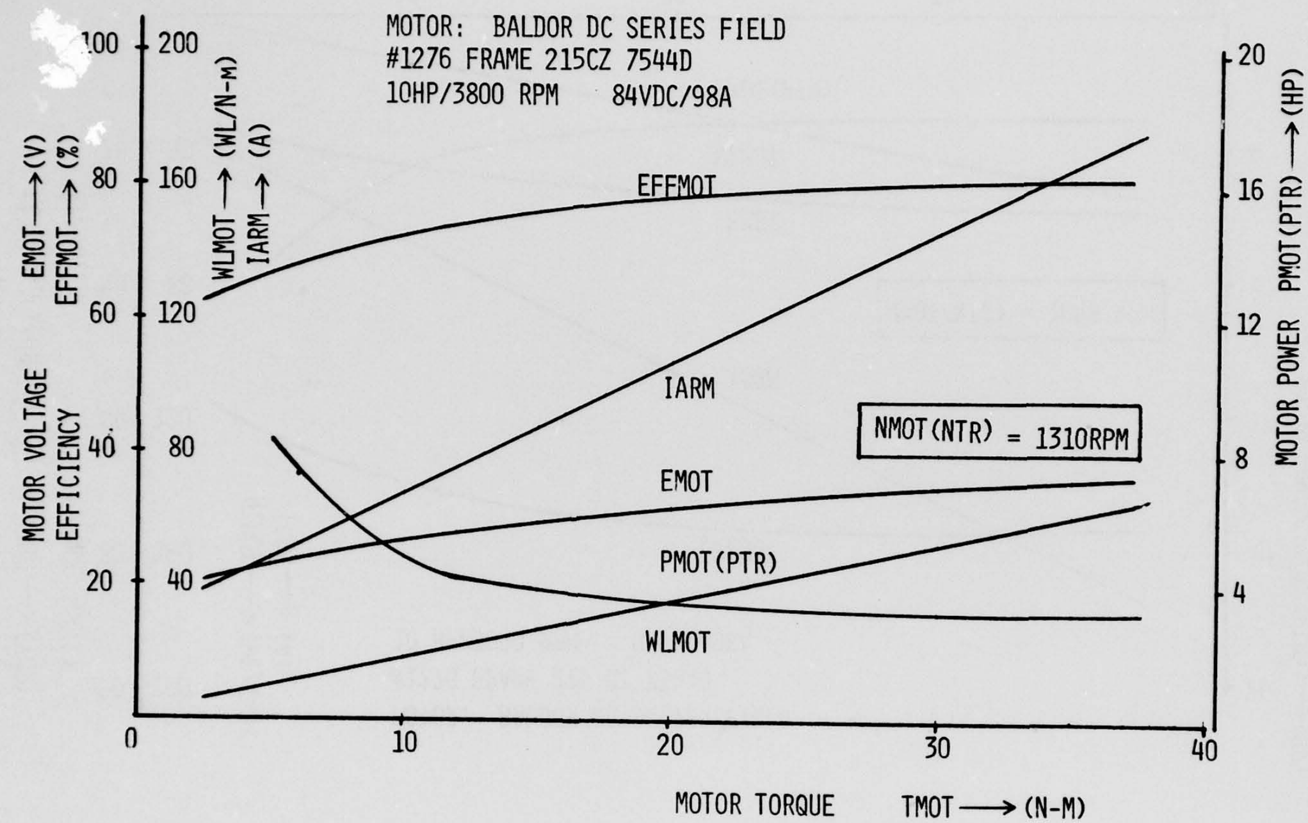


Figure 12.13D. Parametric test data @ NMOT = 1310 RPM.

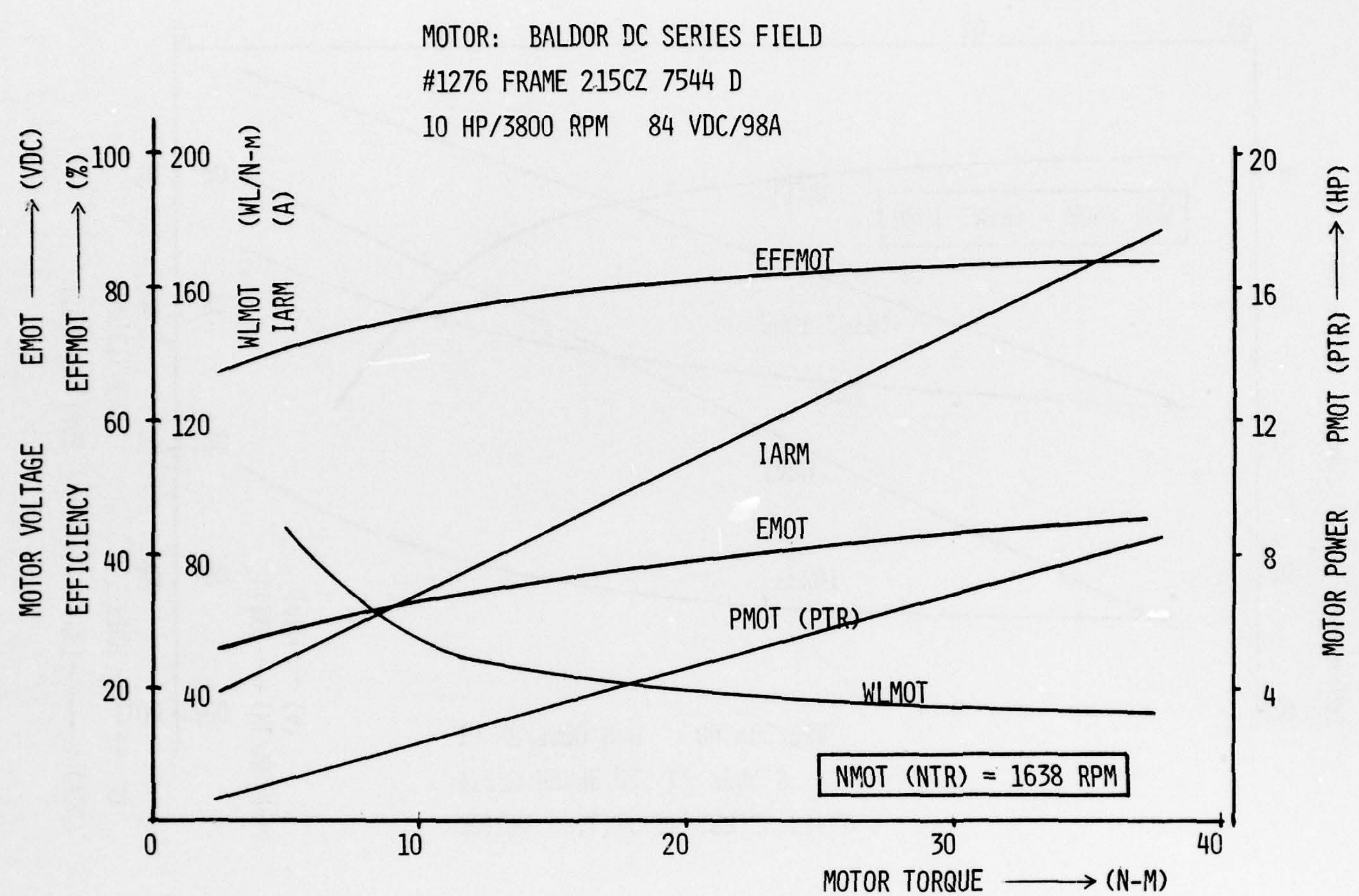


Figure 12.13E. Parametric test data @ NMOT = 1638 RPM.

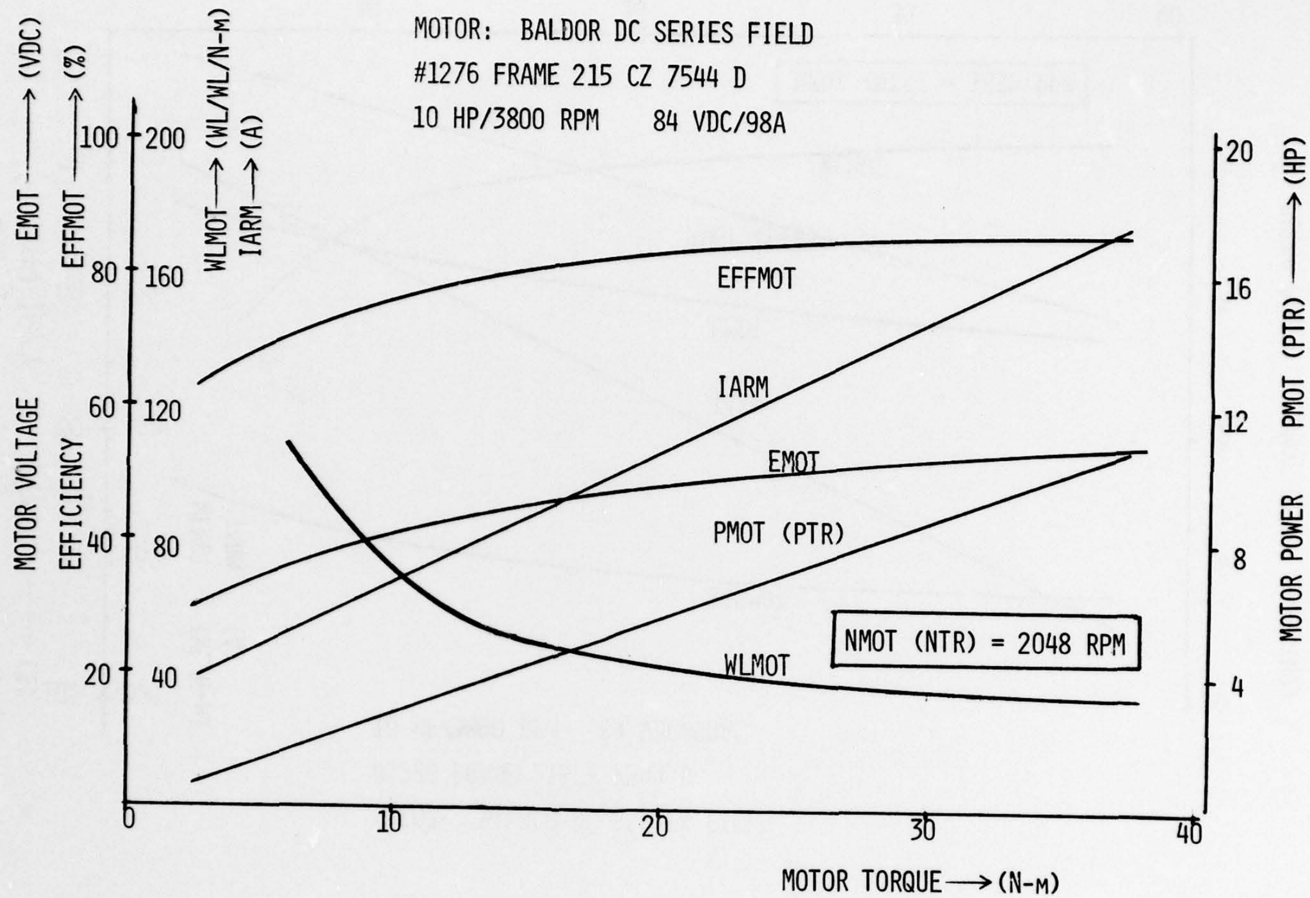


Figure 12.13F. Parametric test data @ NMOT = 2048 RPM.

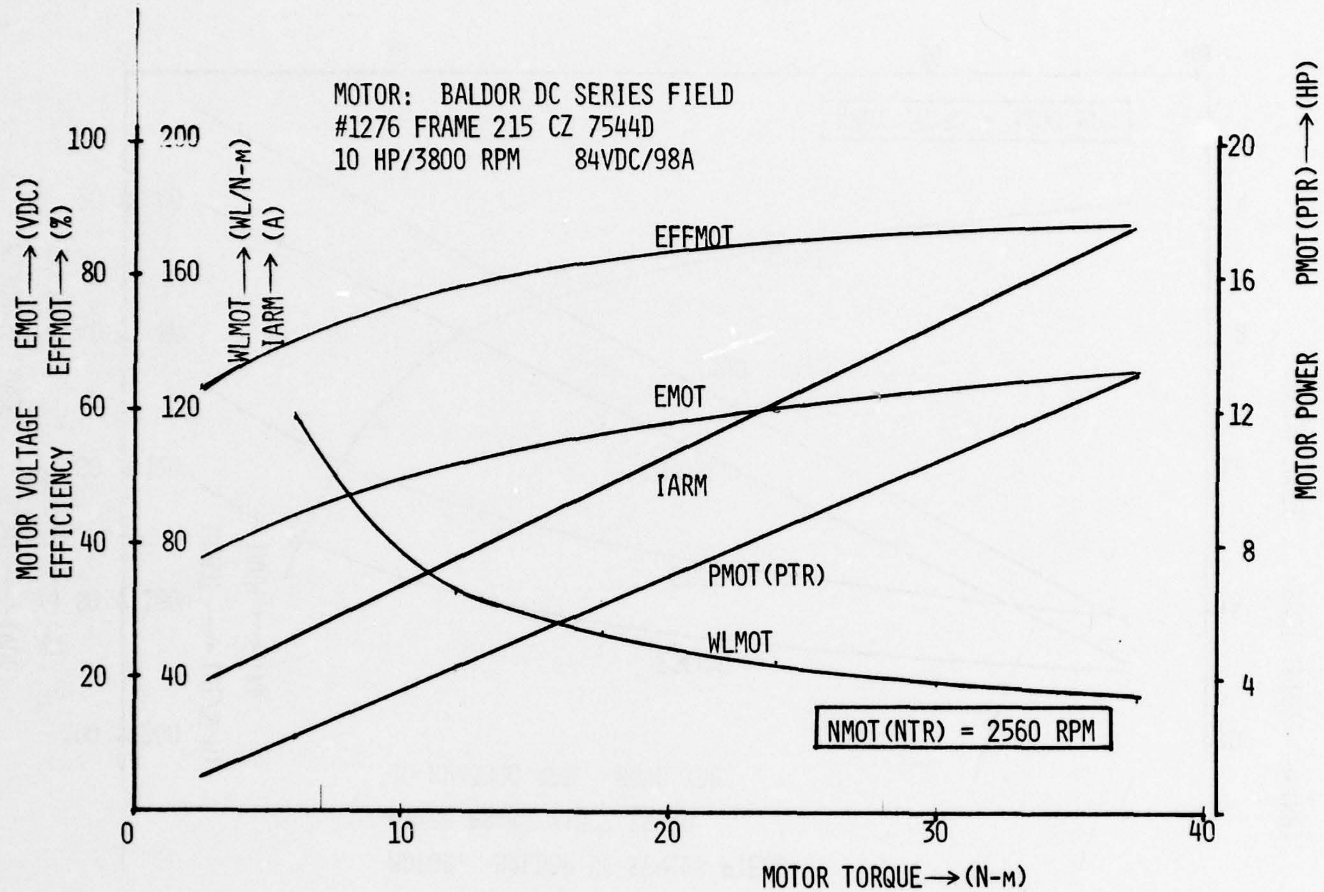


Figure 12.13G. Parametric test data @ NMOT = 2560 RPM.

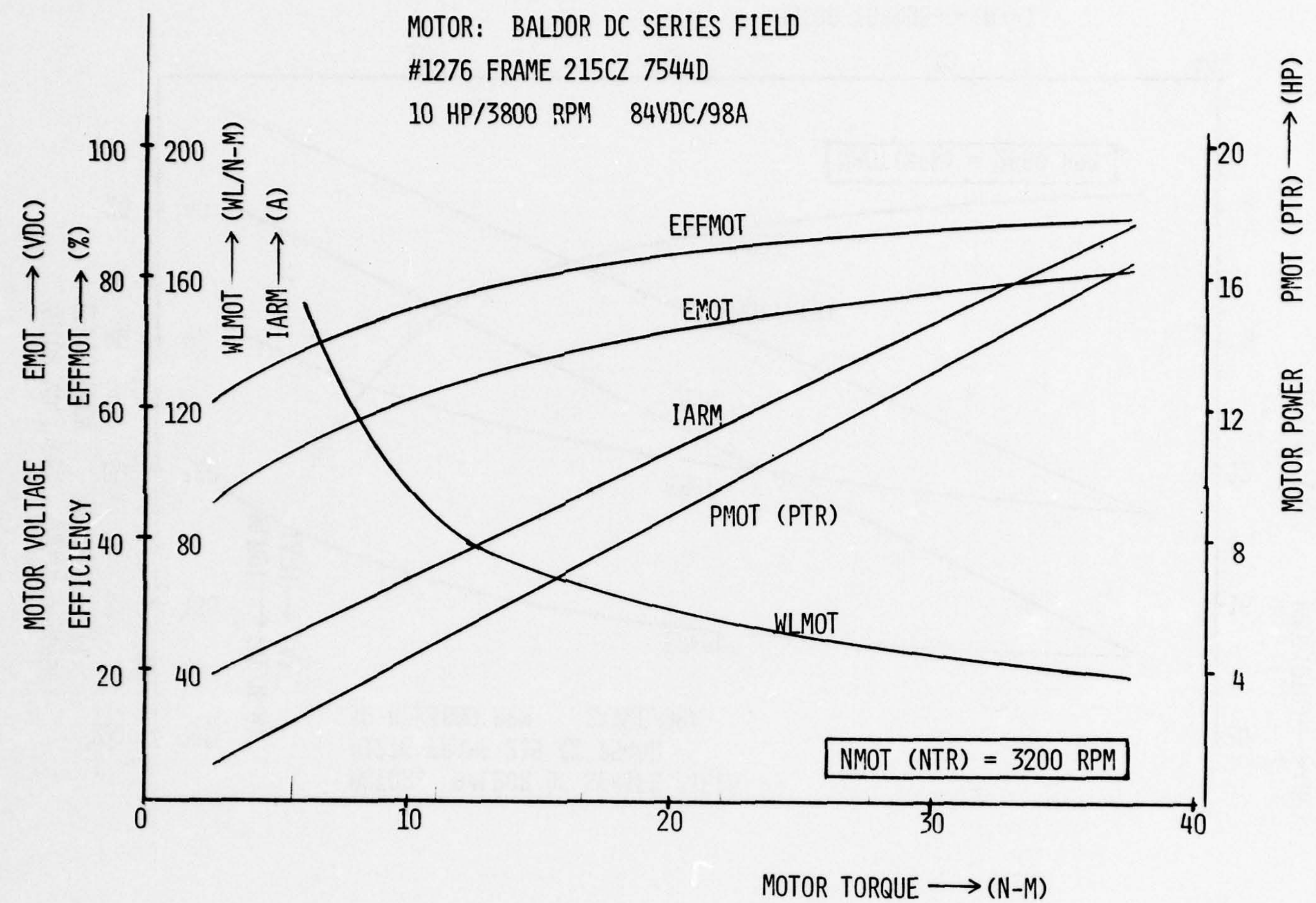


Figure 12.13H. Parametric test data @ NMOT = 3200 RPM.

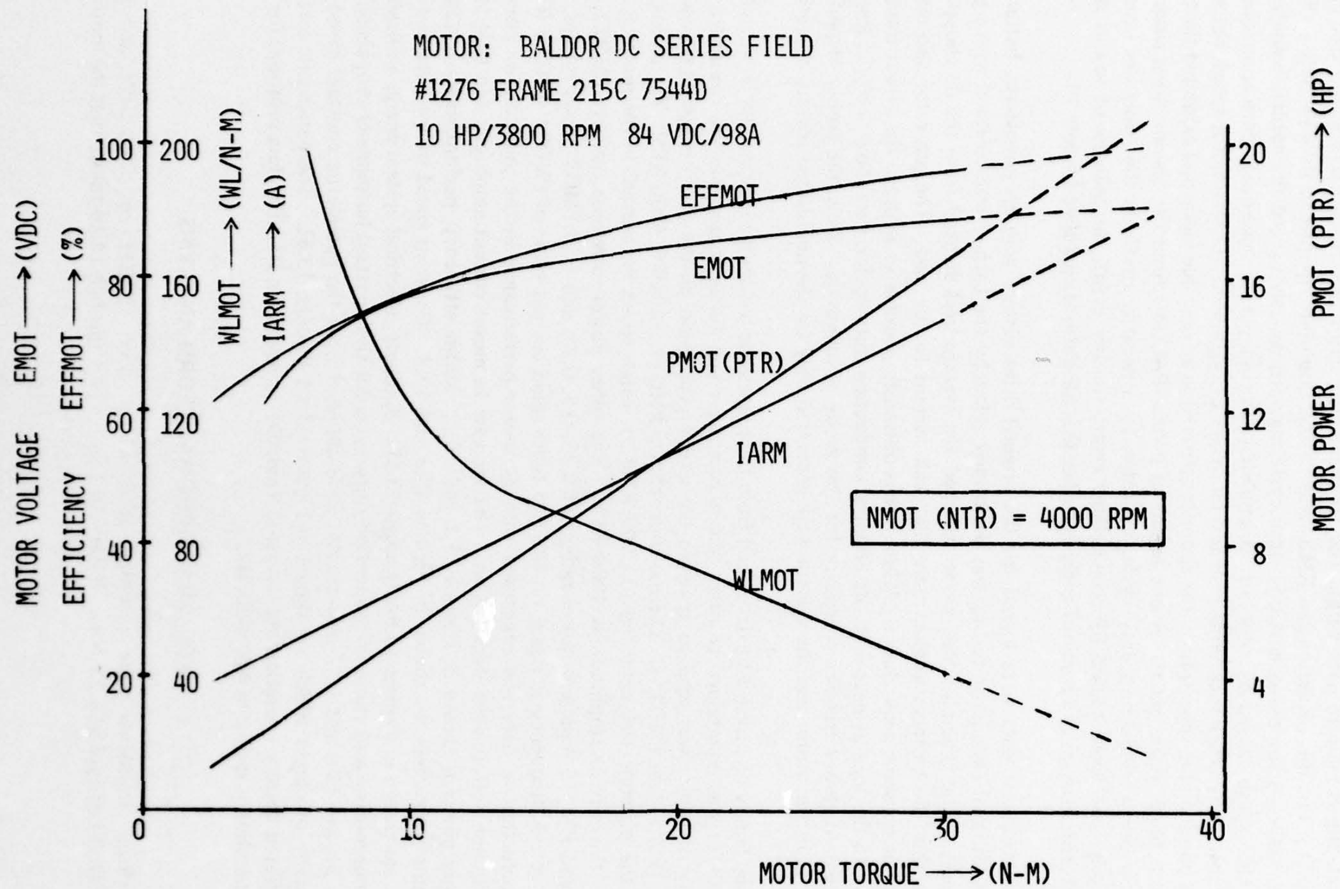


Figure 12.131. Parametric test data @ NMOT = 4000 RPM.

Because neither the voltage nor the current form factor can exceed an amplitude ratio RMS/AVG $\geqslant$ 1, parametric data read-outs above unity at light load profiles are caused by noise or computation error when correlating composite data within the HP9825A calculator, and do not represent a true condition of the circuit. For this condition the RMS value of the amplitude is equal to its AVG value. Similarly, parametric read-outs for the conduction duty cycle may erroneously exceed the natural boundary limits $0<\Delta<1$. This is also caused by noise, or accumulated error margin, or inadequate data accumulation due to system instability when measuring over several cycles of operation. At low motor speed, but nevertheless over a considerable speed range, the chopper operated in an unstable mode and exhibited the tendency to skip each third trigger pulse. A net return of power (PACOM) from the commutating circuit to the battery near unity conduction duty cycle, indicated by a negative prefix in the computer print out, is most unlikely, and again caused by accumulated error. In any event, the increase of any of the aforementioned error margins as a result of analysis within the calculator is considered below 1%.

Parametric test data were logged for the original drive system with an unbuffered battery power supply. Additional parametric testing was performed, whereby the battery was buffered with a generator power supply. The generator load curve matched the average load demand from the dc chopper motor drive such that the battery supplied only the peak current to the load. The generator also maintained the battery at constant peak charge. While it was obviously possible to improve the power transfer from the battery to the load at near unity dc chopper conduction duty cycles, data show only an insignificant improvement of power transfer efficiency for this mode of operation. Thus, the family of performance curves for both the motor and the system were generated only for the unbuffered battery operating mode

A basic family of curves were developed from the parametric test shown in Appendix D, whereby motor speed (NMOT) was maintained constant and a parameter and motor torque was the controlled variable. The family of curves was used to generate the motor propulsion profile for five constant power rating envelopes [PMOT1 to PMOT5]. The motor is rated at PMOT1 =10kW@ 4000 RPM. The constant power rating of the machine was extended to 2000 RPM at which speed the current in the motor is typically two times the current amplitude at 4000 RPM. The other power envelopes, namely PMOT2, PMOT3, PMOT4, and PMOT5 represent power ratings of 0.75, 0.5, 0.25, and 1.25 PMOT power ratings, whereby each low corner frequency is based on the two times rated current value of PMOT1 @ 4000 RPM. Additional reduction of data was concerned with dc motor performance in the pulsating dc power mode and subsequent performance degradation. The increase in motor current amplitude and field losses due to pulsating power is shown in Figures 13.1 and 13.2. Motor efficiency, performance degradation and other motor parameters are shown in Figures 13.3 and 13.4. Constant speed motor data as a function of torque are shown in Figures 13.5A through 13.5L. Similarly, electrical system energy utilization without the transmission and chopper conduction duty cycle for five constant horsepower propulsion profiles, shown in Figures 13.6 and 13.7 respectively, were obtained from the parametric constant speed, variable torque family of curves which are shown in Figures 13.8A through 13.8L. The parametric test data for the unbuffered battery operation are shown in Table D1 in Appendix D1. The data print-out for buffered battery operation is shown in Appendix D2.

XIV. TRANSIENT WAVEFORM ANALYSIS

Waveform transients were recorded at a motor speed (NMOT) of 200 RPM and a motor torque (TMOT) of typically 23 N-m. Review of Figures 14.1 through 14.10 shows that the motor current

XIII-1. MOTOR PERFORMANCE.

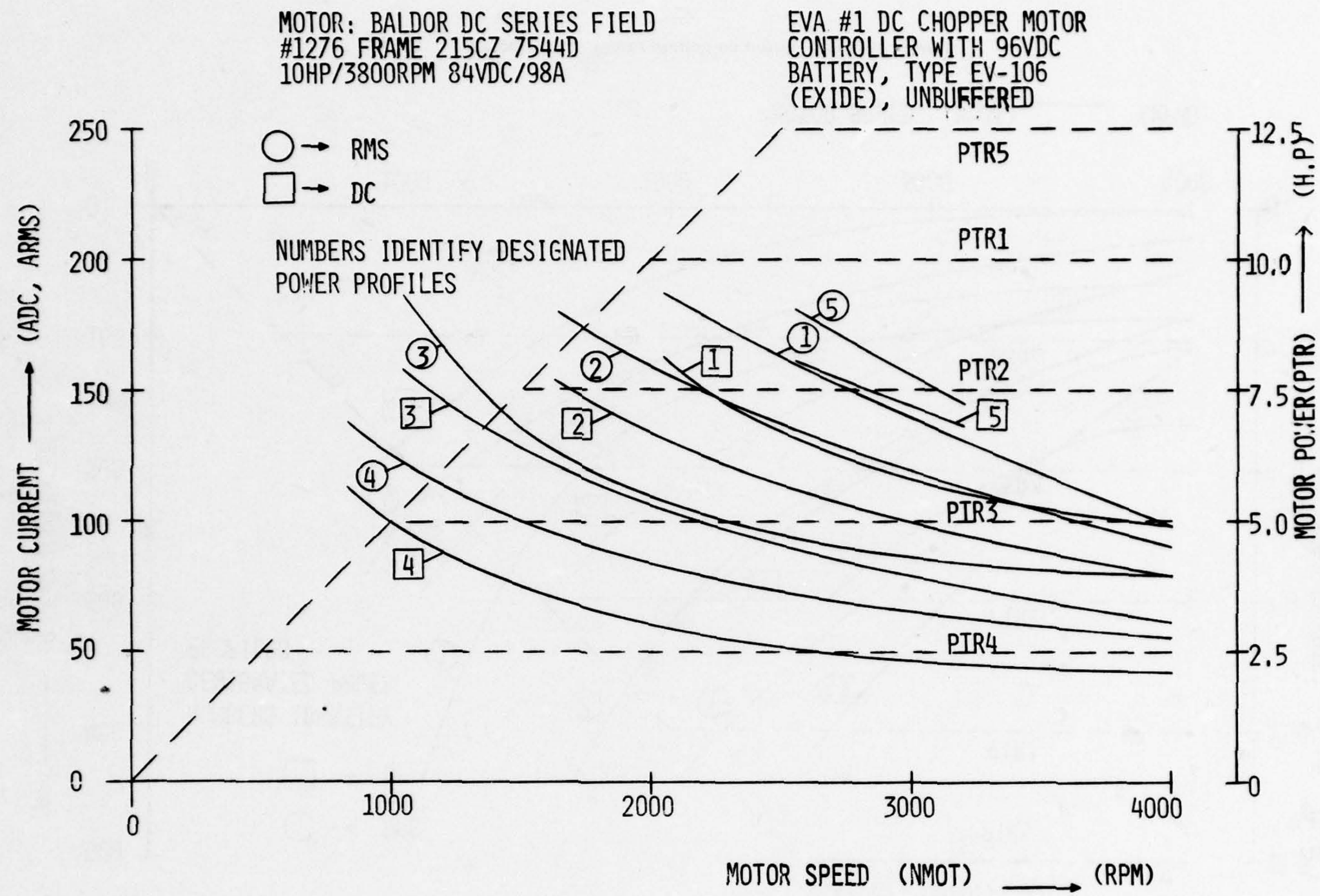


Figure 13.1. Motor propulsion profile, pulsed DC power.

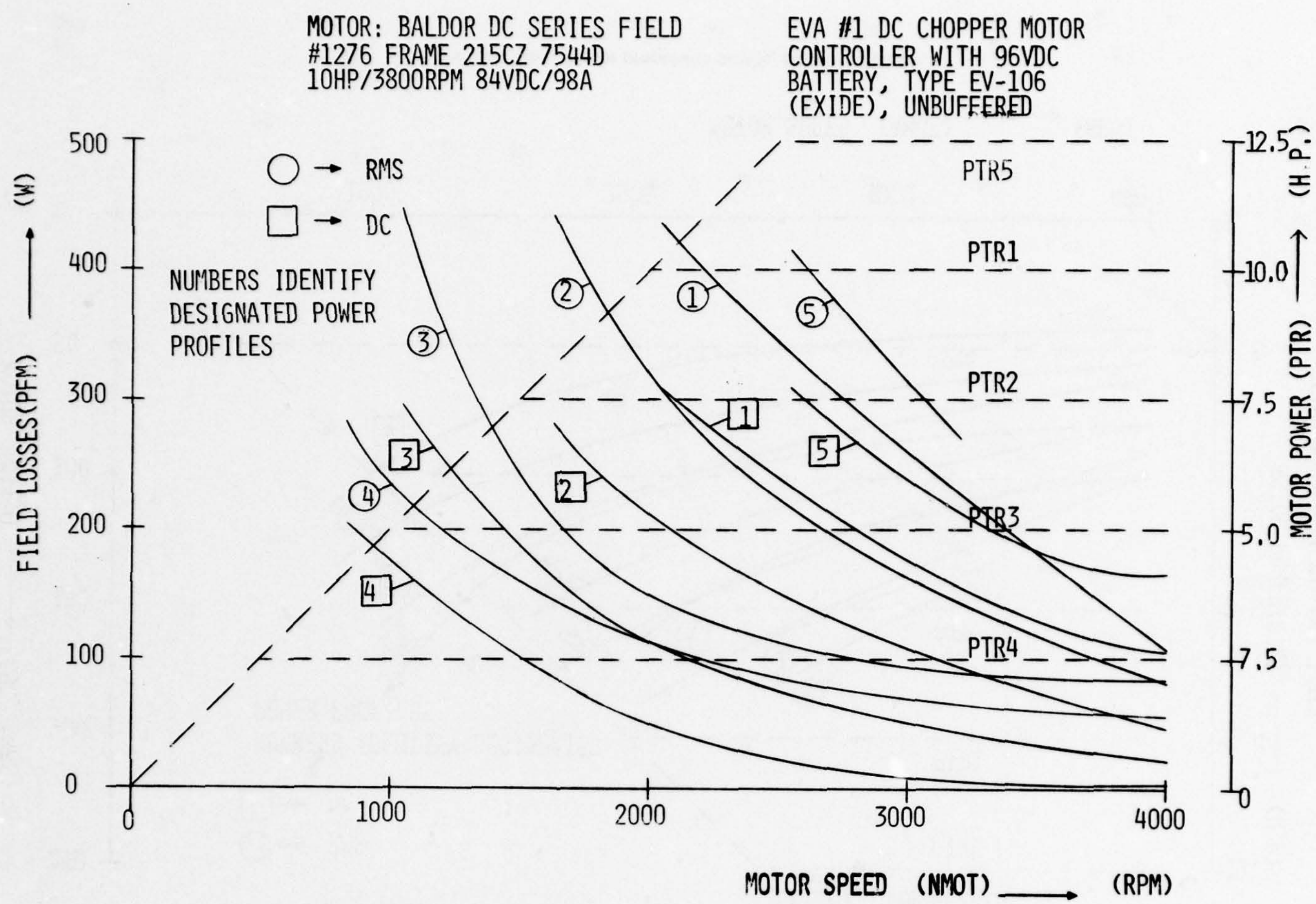


Figure 13.2. Motor propulsion profile, pulsed DC power.

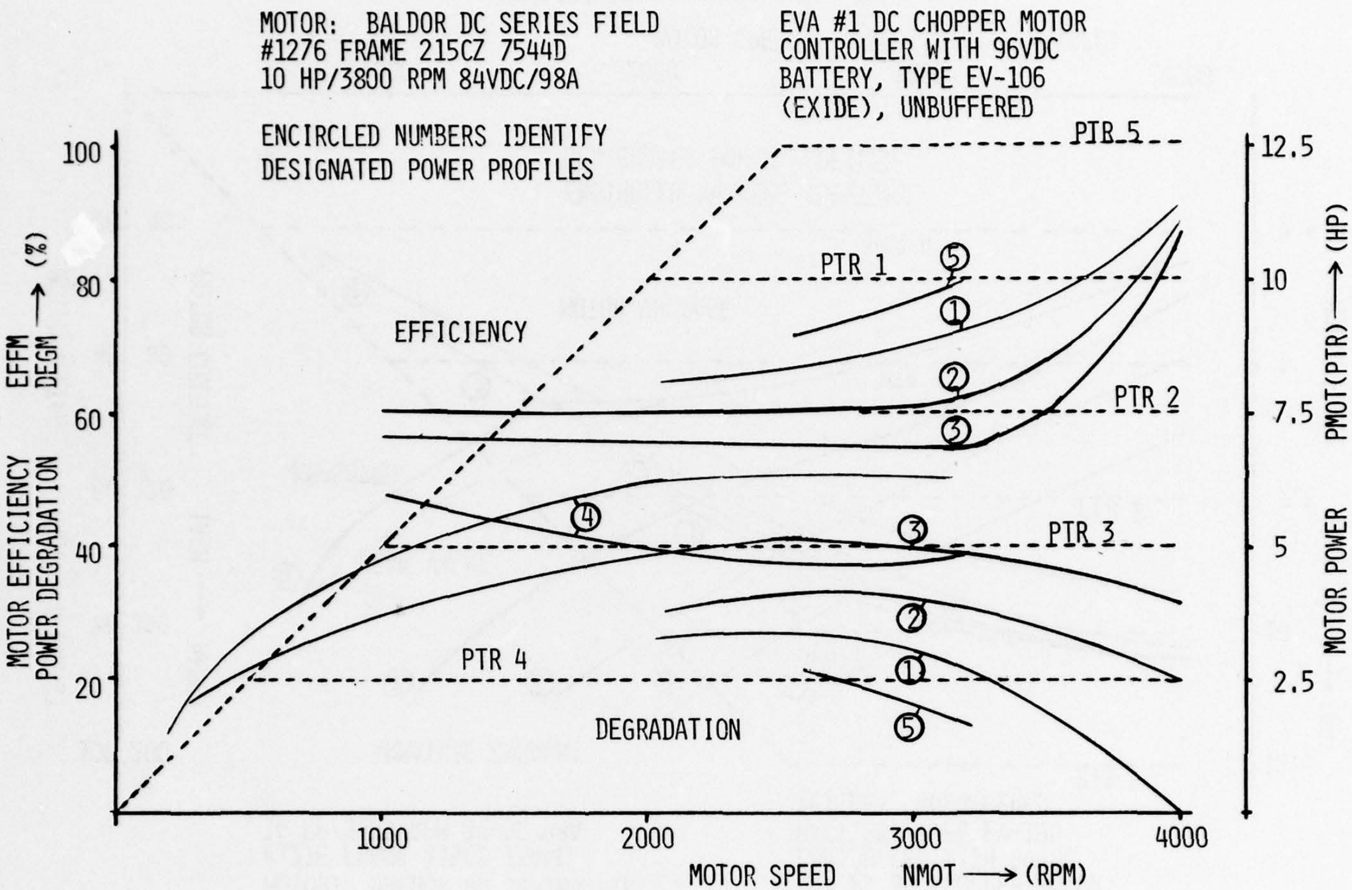


Figure 13.3. Motor propulsion profile, pulsed DC power.

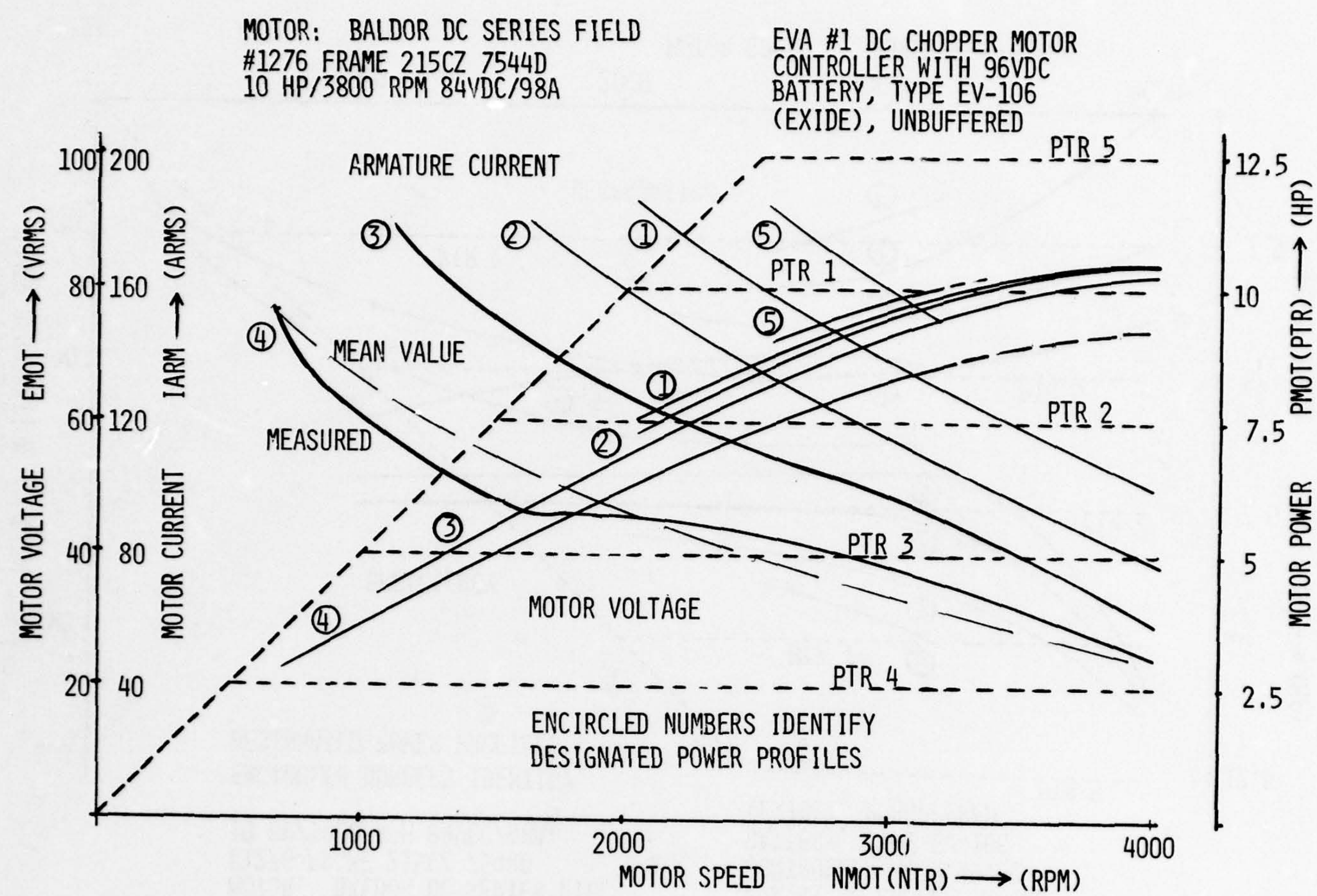


Figure 13.4. Motor propulsion profile, pulsed DC power.

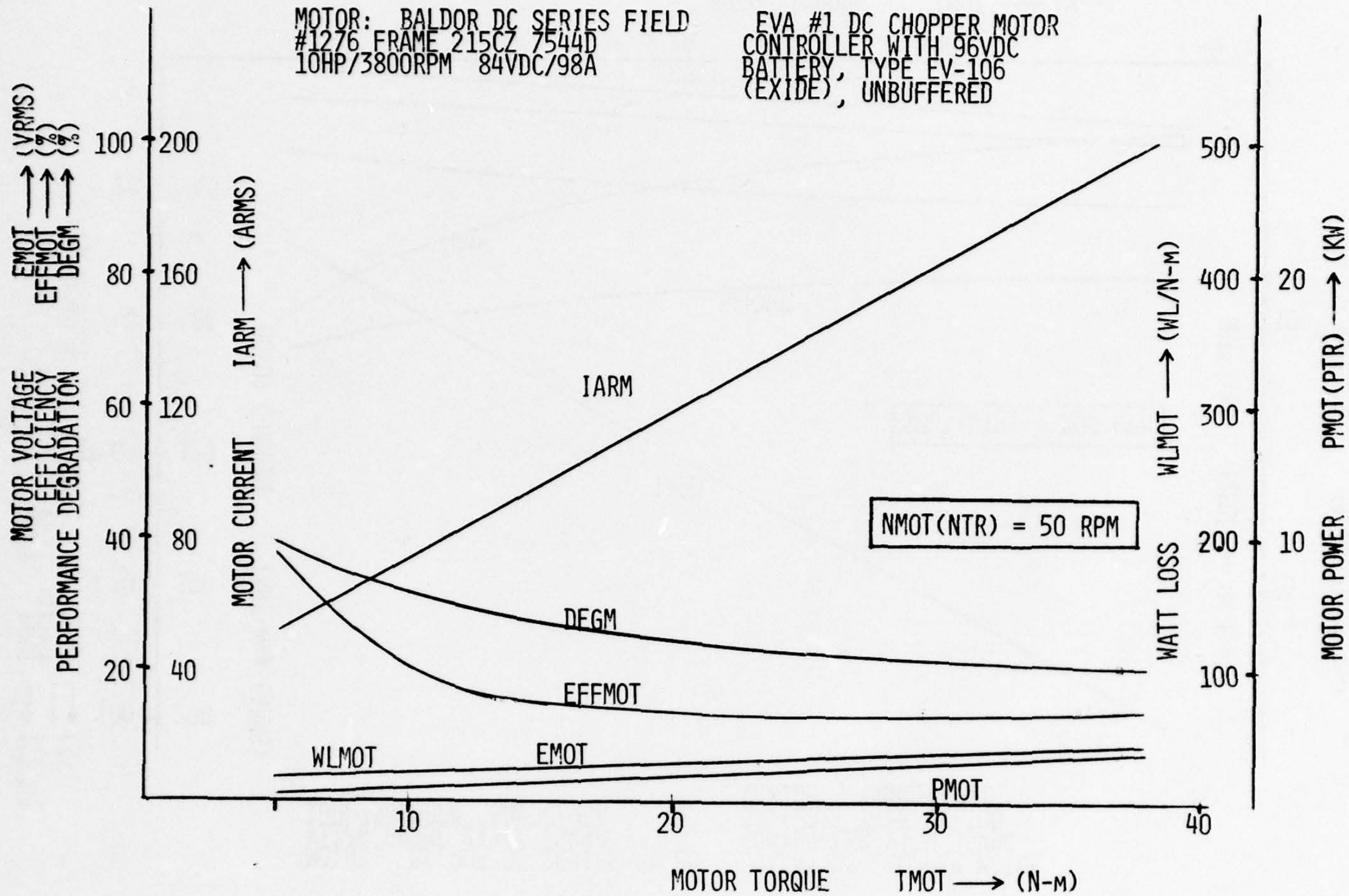


Figure 13.5A. Motor performance @ 50 RPM, pulsed power.

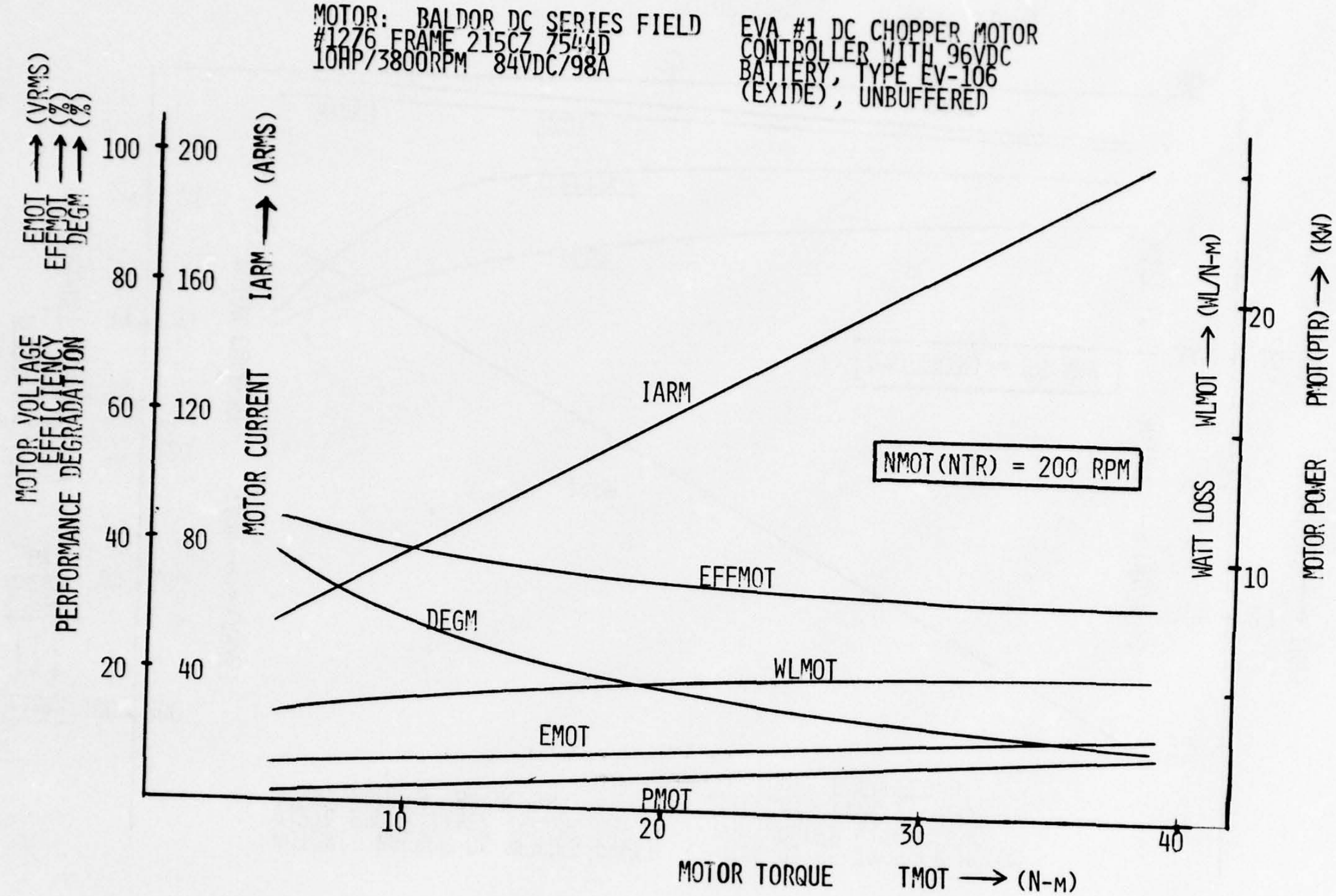


Figure 13.5B. Motor performance @ 100 RPM, pulsed DC power.

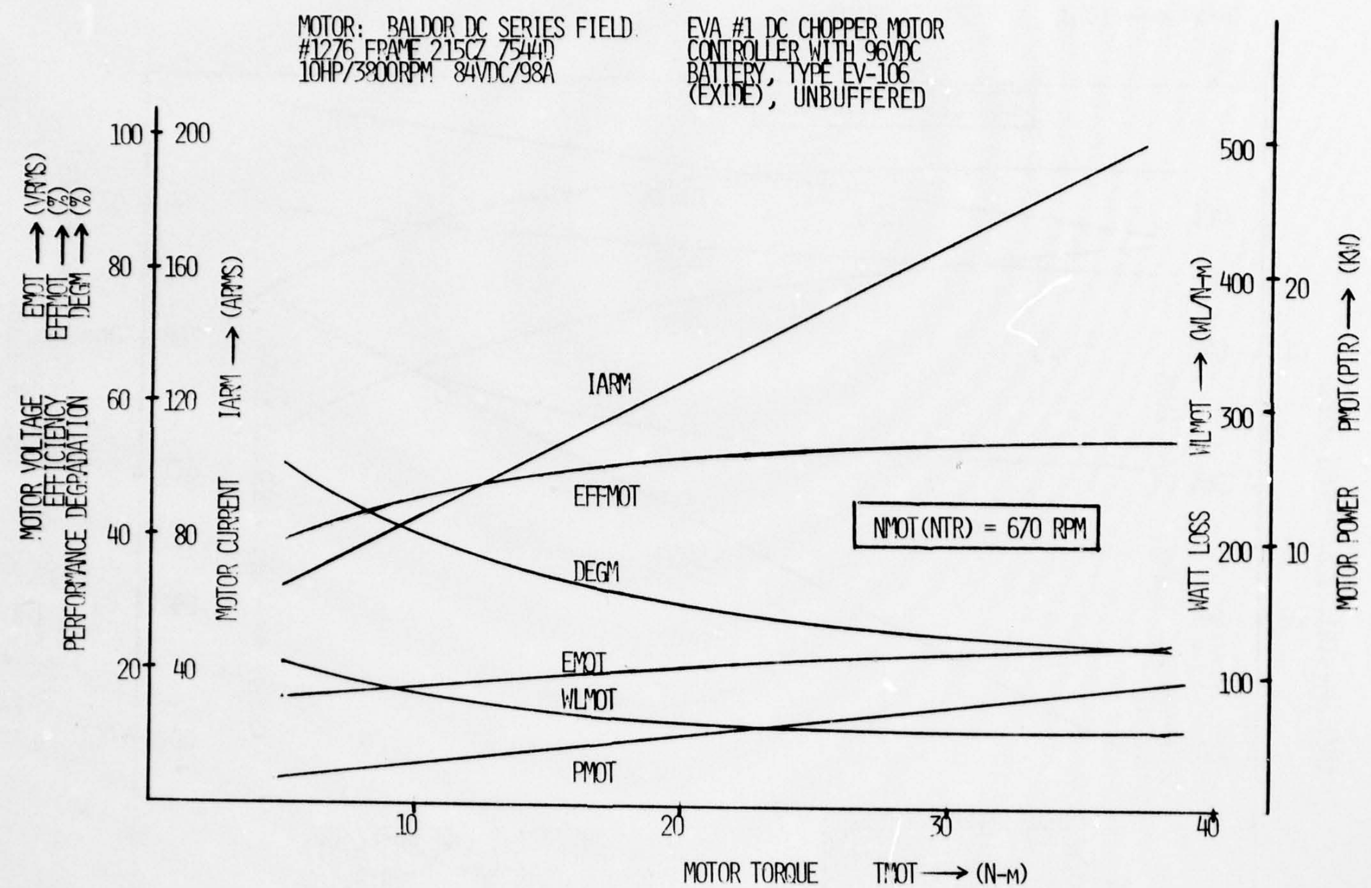


Figure 13.5C. Motor performance @ 670 RPM pulsed DC power.

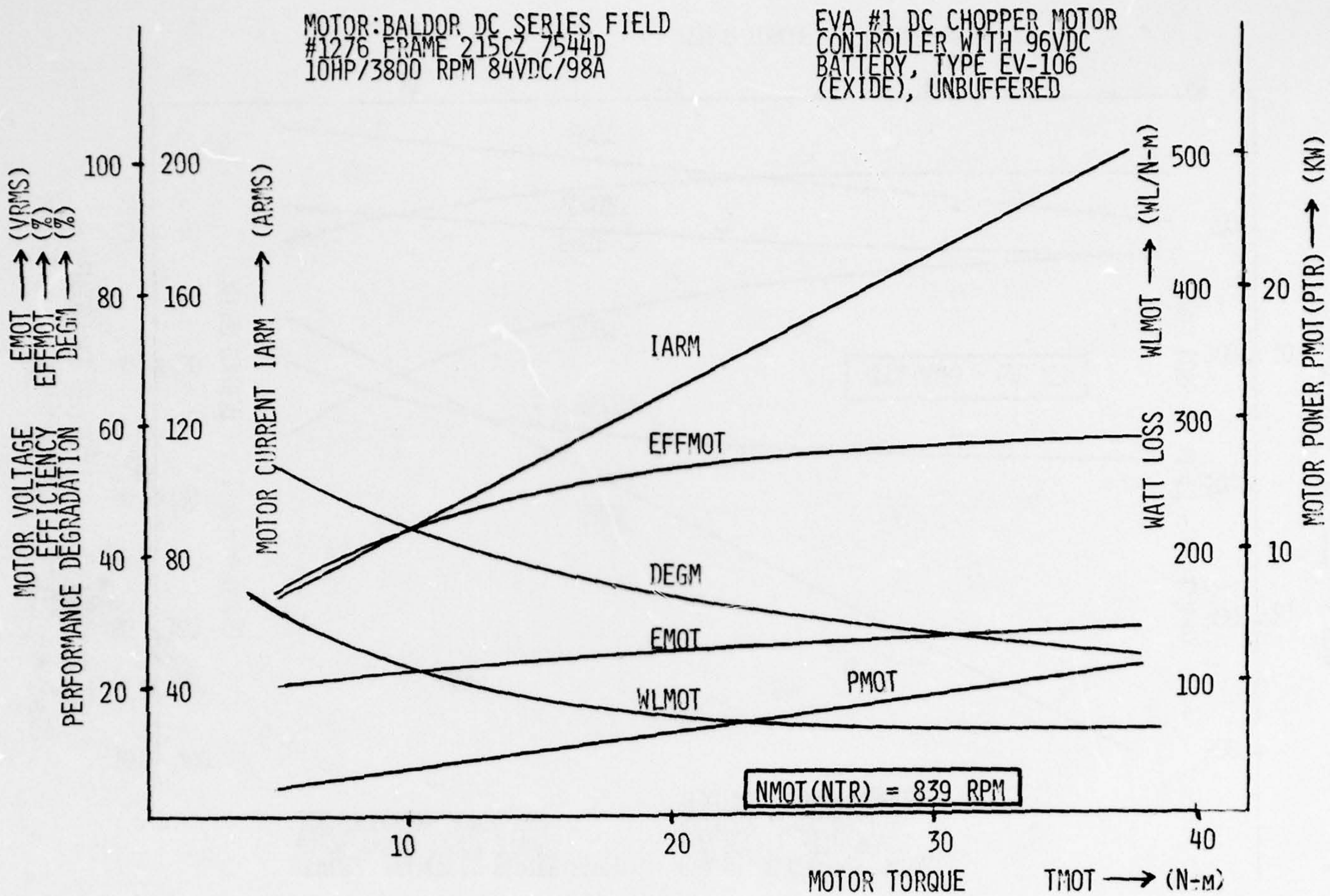


Figure 13.5D. Motor performance @ 839 RPM, pulsed DC power.

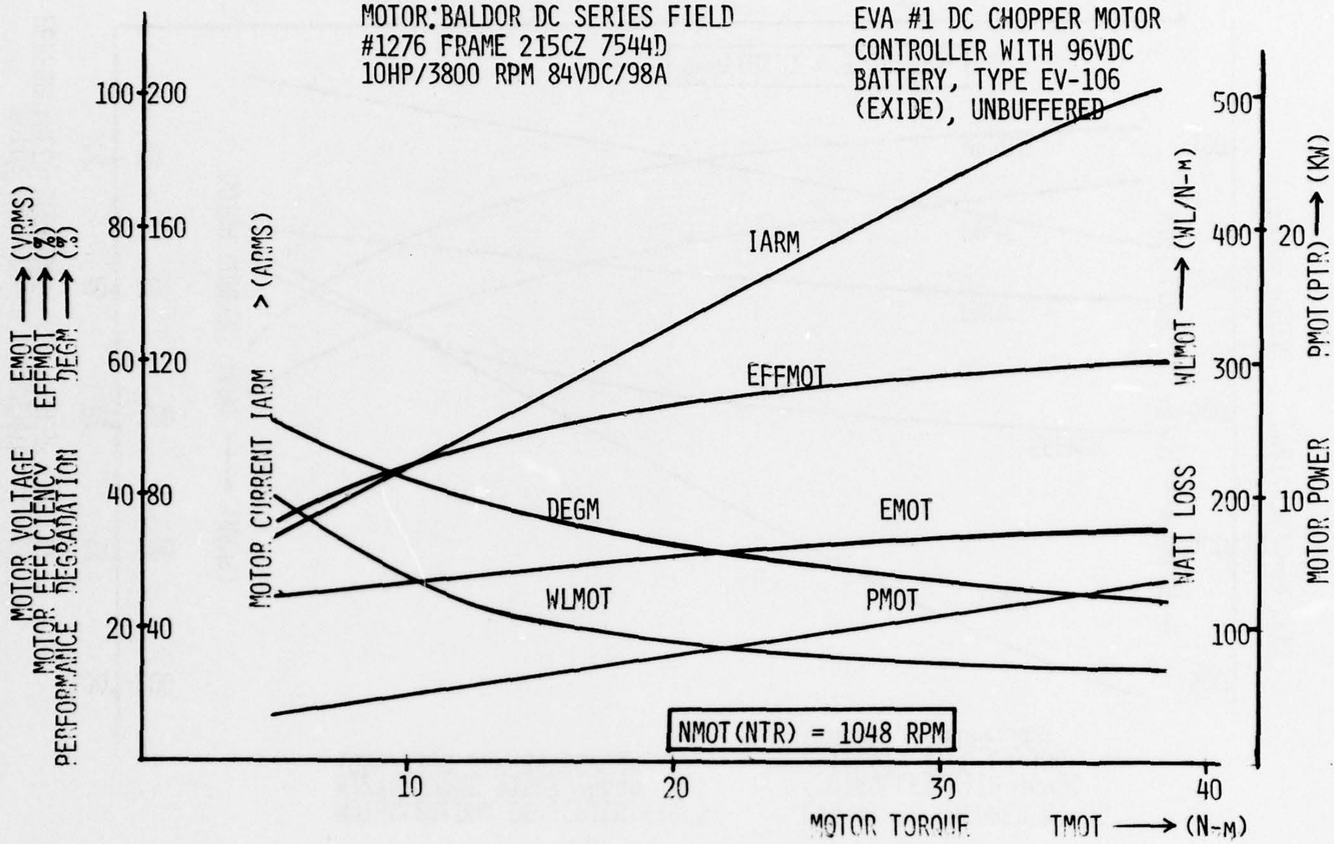


Figure 13.5E. Motor performance @ 1048 RPM, pulsed DC power.

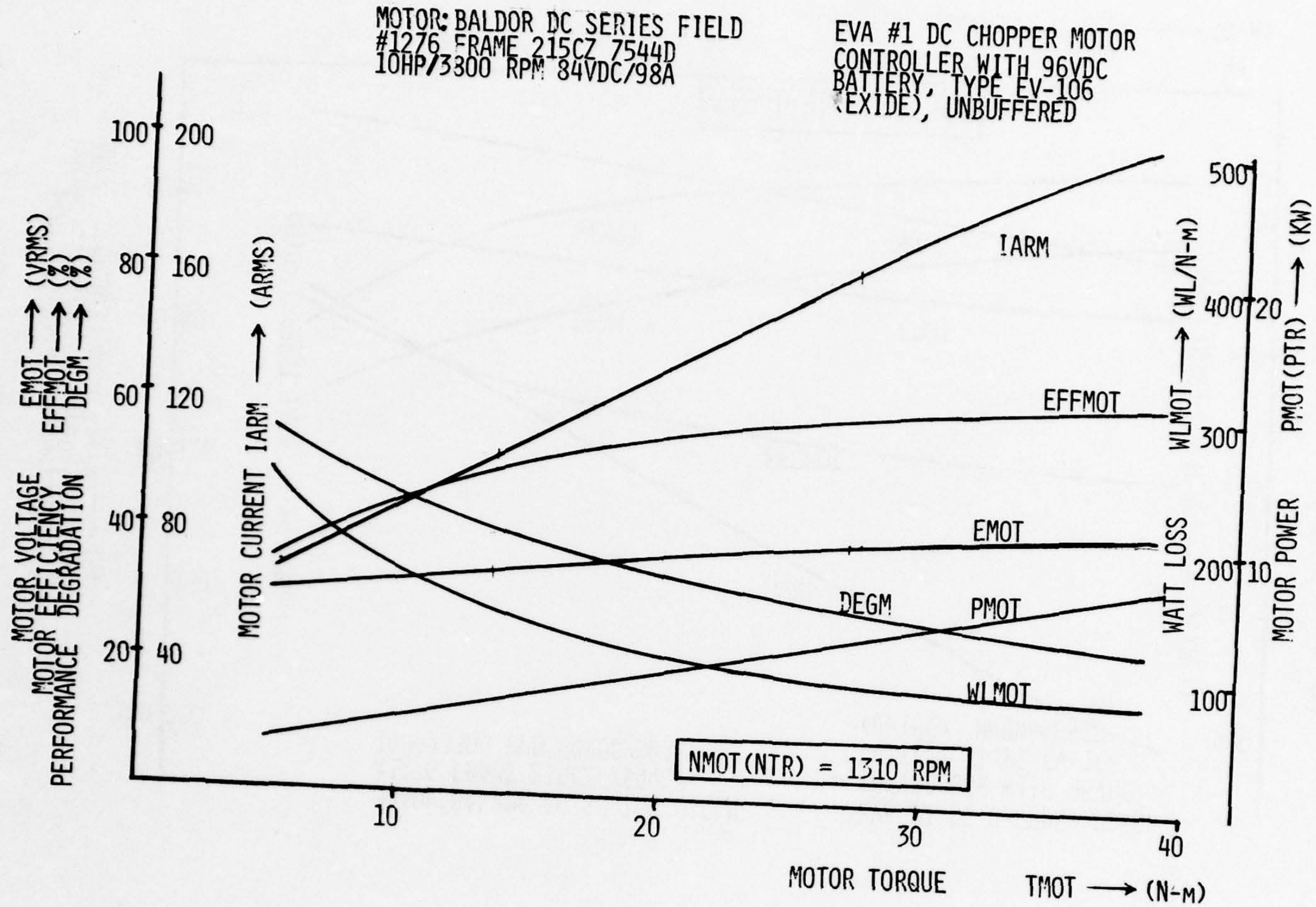


Figure 13.5F. Motor performance @ 1310 RPM, pulsed DC power.

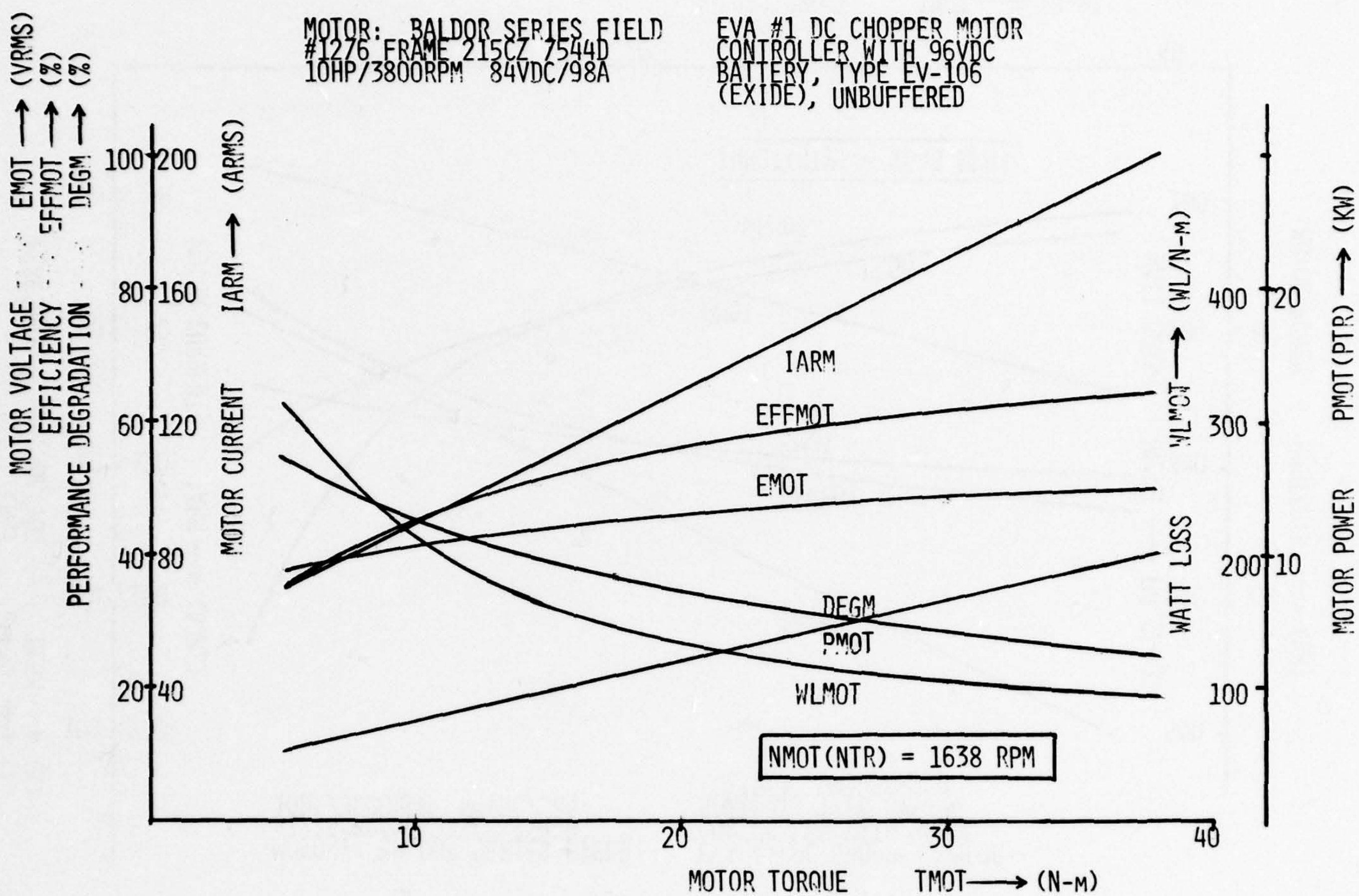


Figure 13.5G. Motor performance @ 1638 RPM, pulsed DC power.

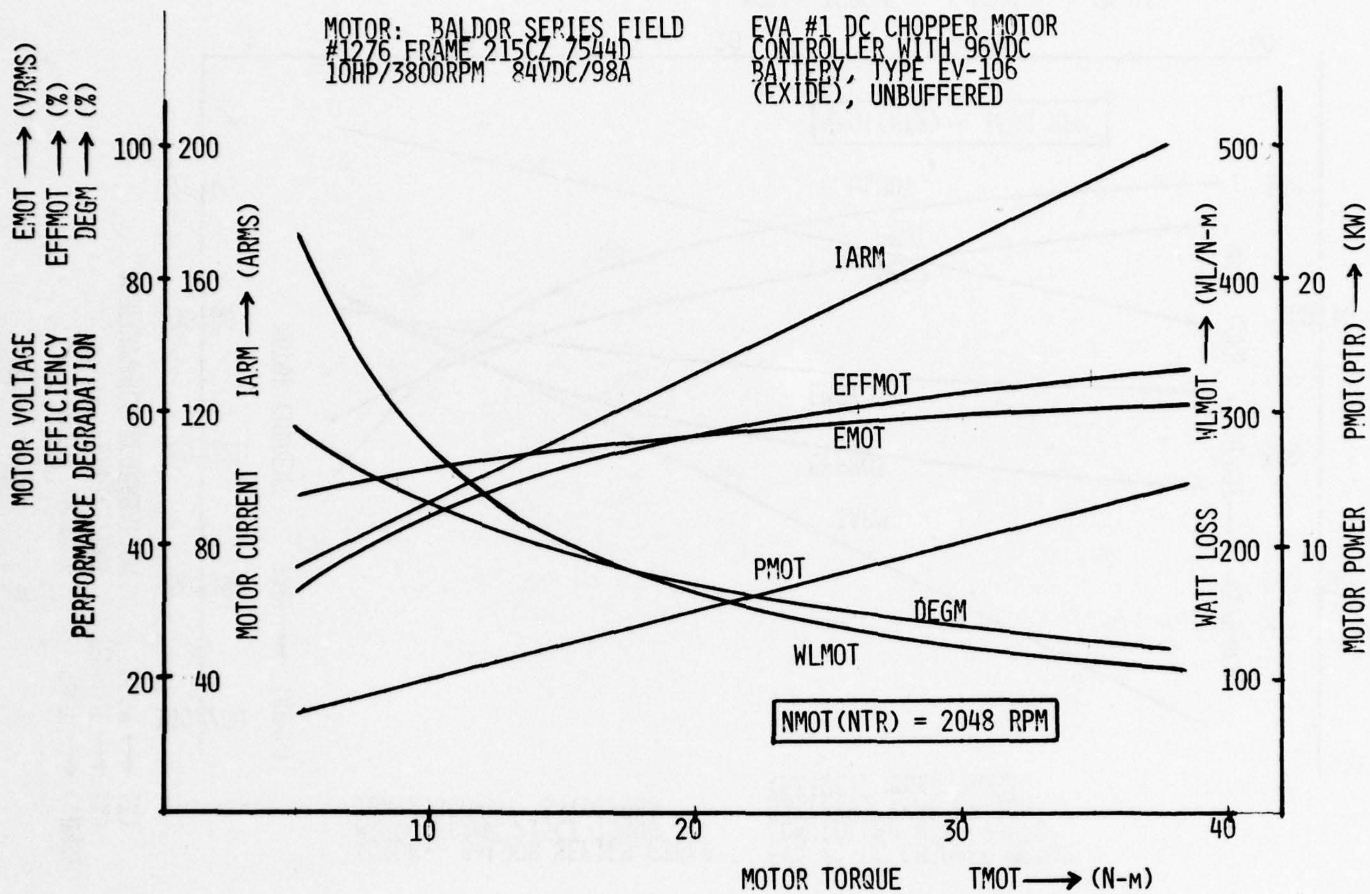


Figure 13.5H. Motor performance @ 2048 RPM, pulsed DC power.

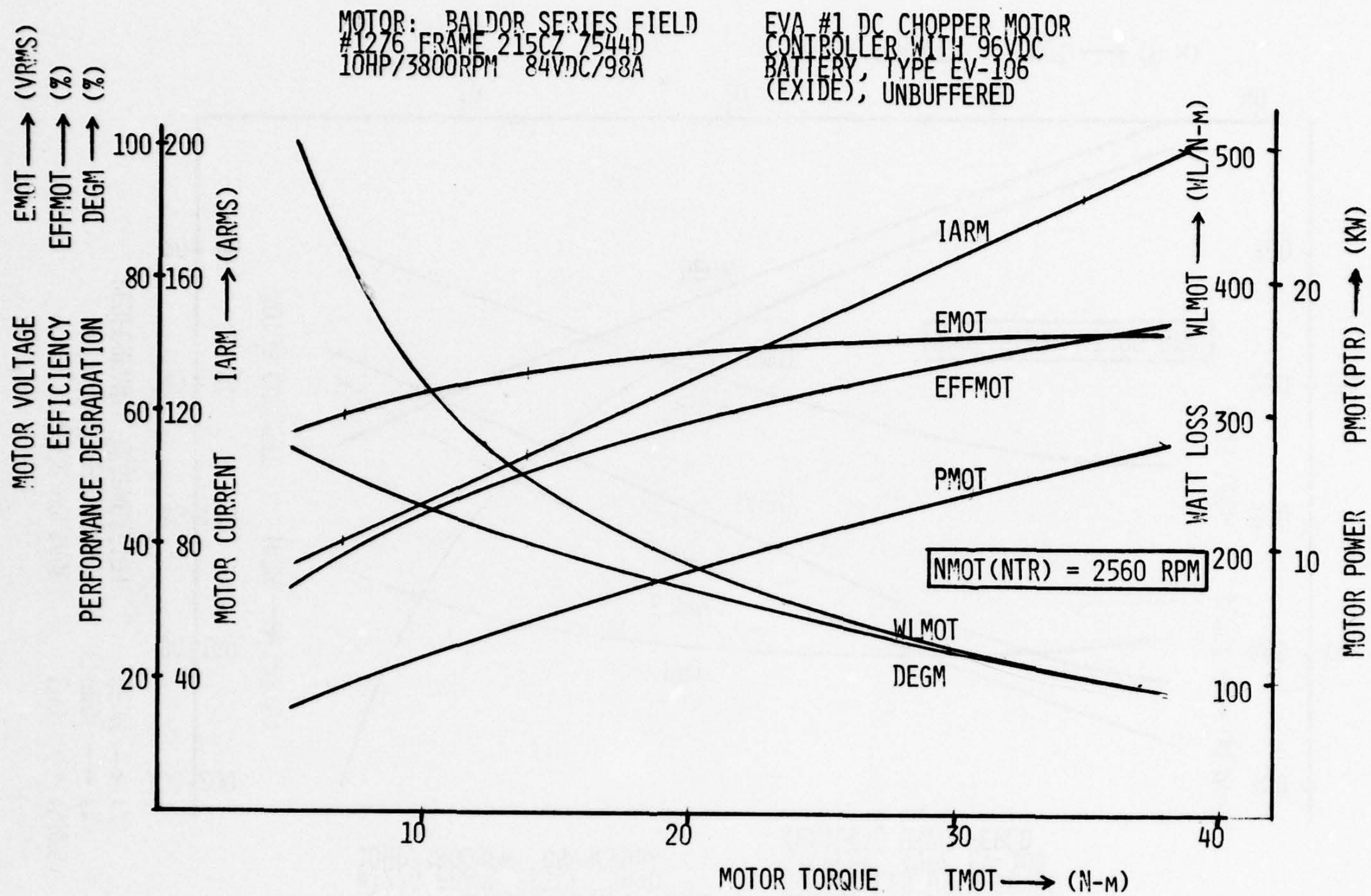


Figure 13.5I. Motor performance @ 2560 RPM, pulsed DC power.

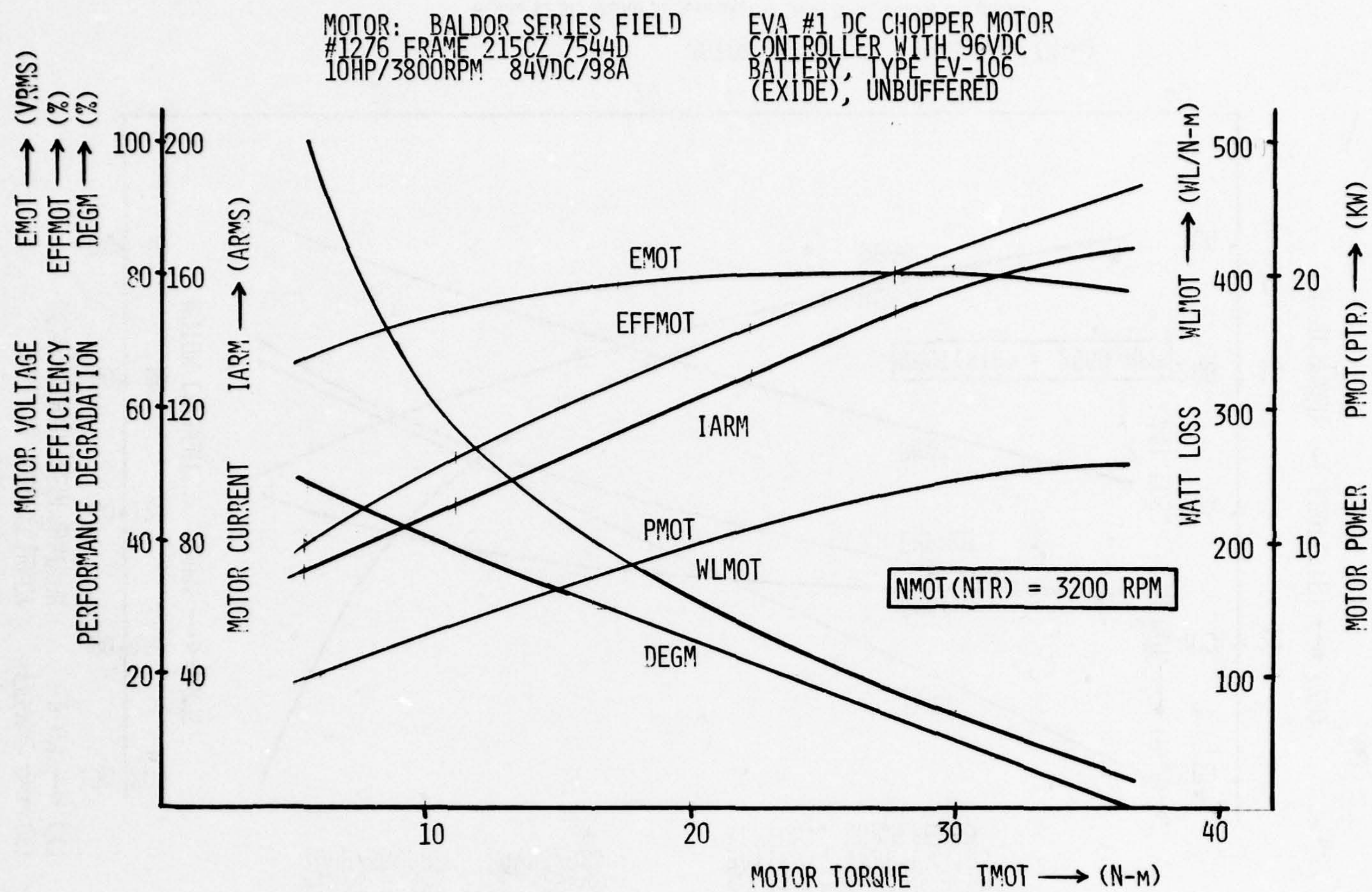


Figure 13.5K. Motor performance @ 3200 RPM, pulsed DC power.

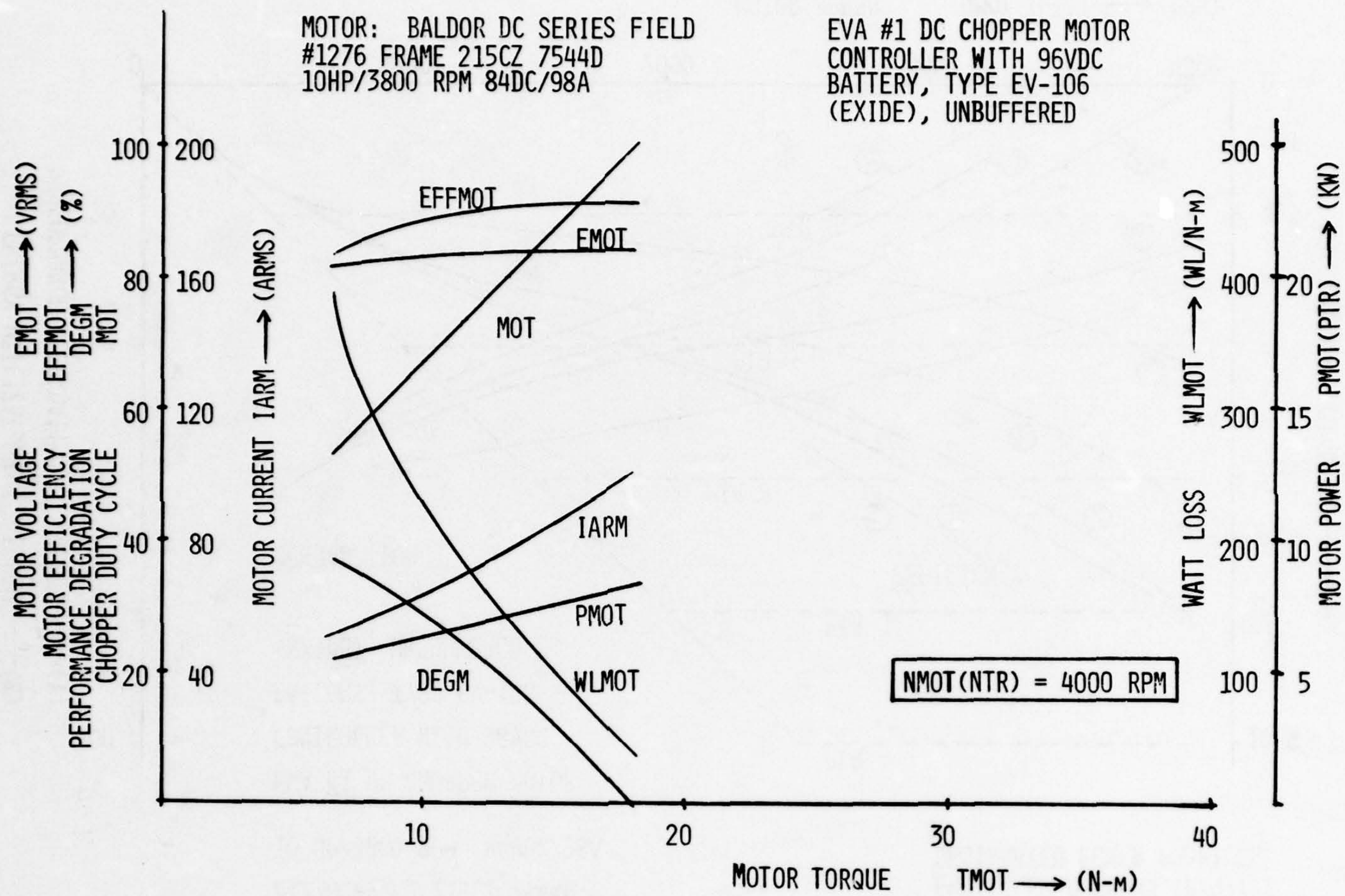


Figure 13.5L. Motor performance @ 4000 RPM, pulsed DC power.

XIII-2. ELECTRIC DRIVE SYSTEM PERFORMANCE, UNBUFFERED BATTERY.

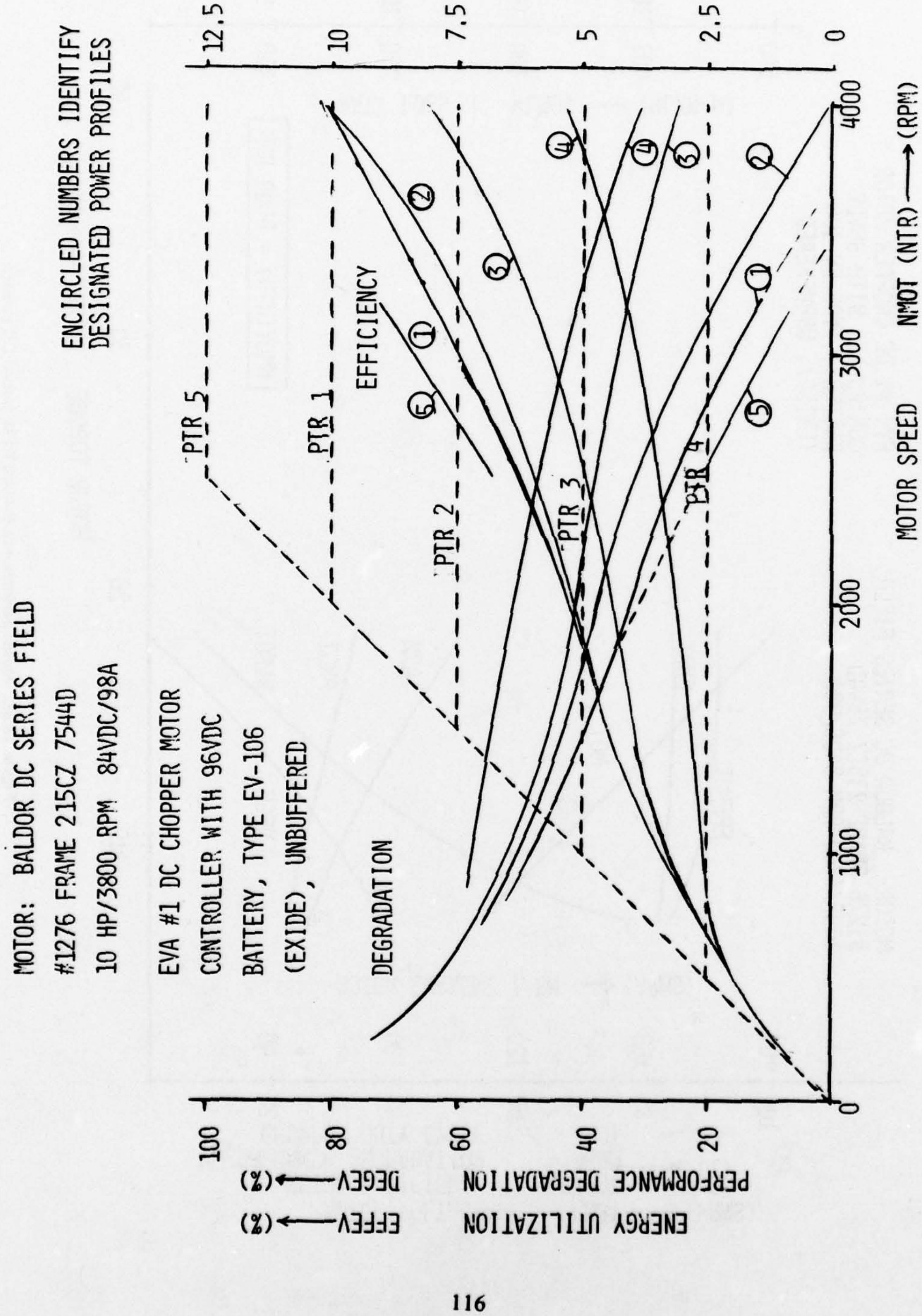


Figure 13.6. System propulsion profile, pulsed DC power.

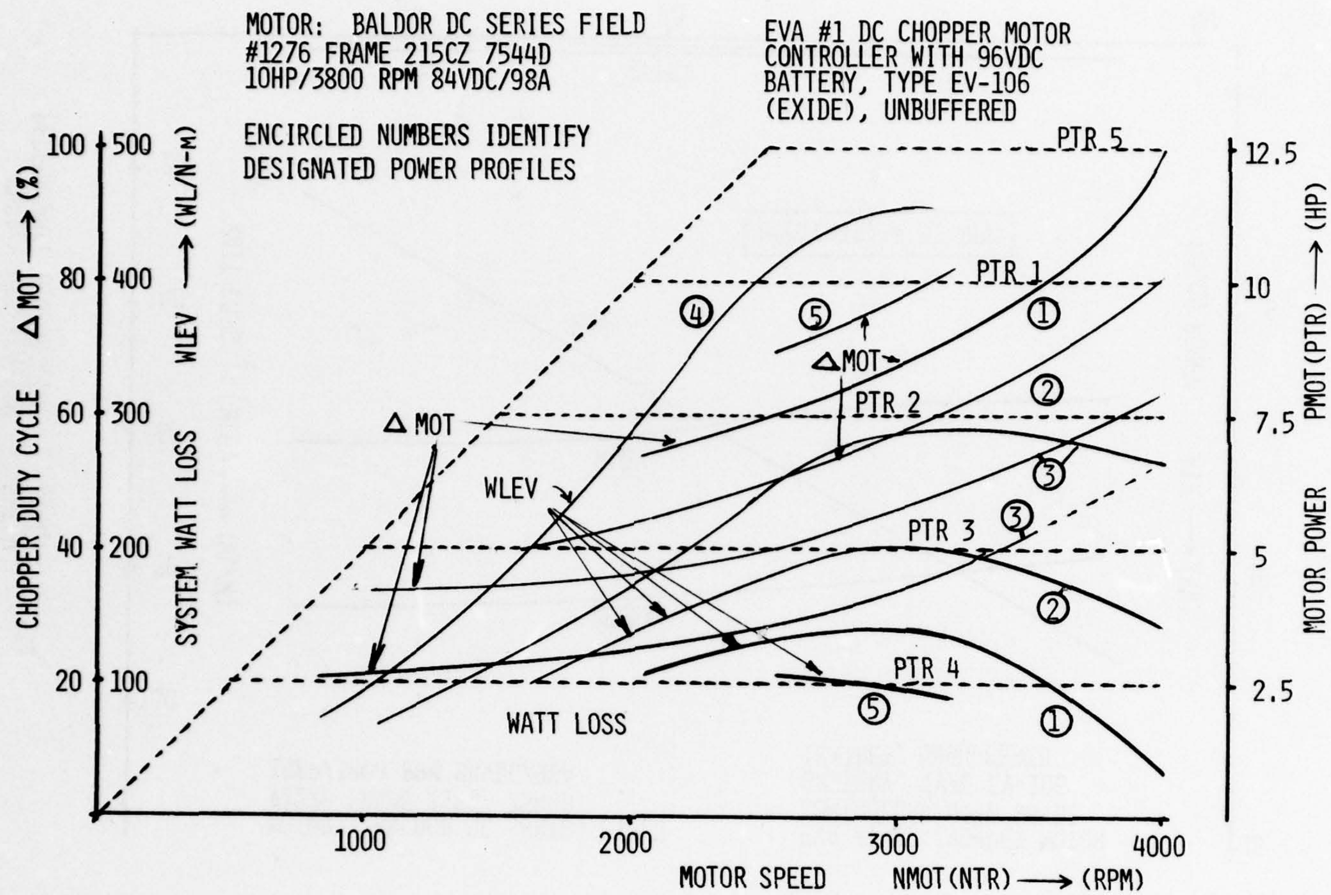


Figure 13.7. System propulsion profile, pulsed DC power.

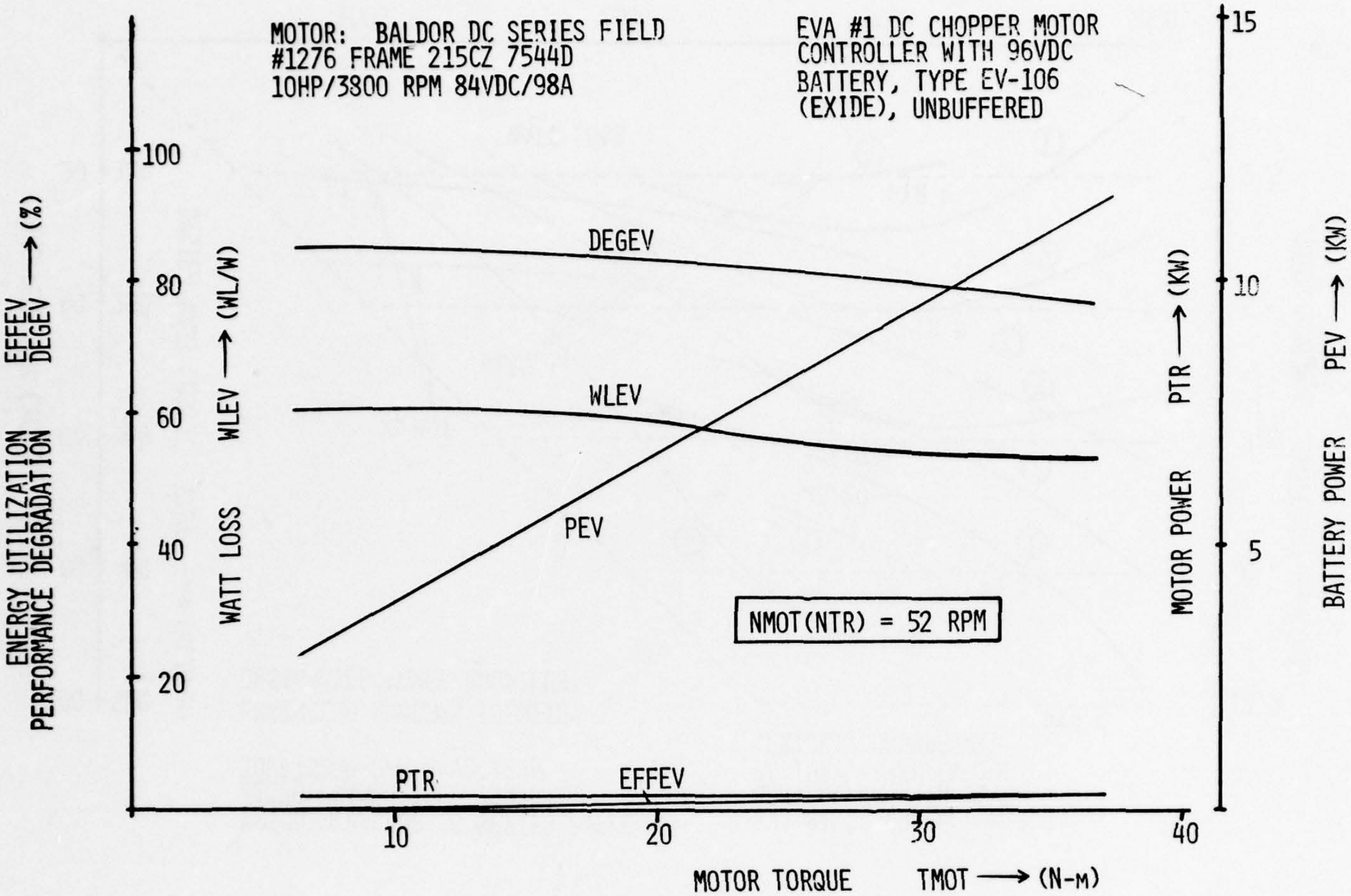


Figure 13.8A. System propulsion profile @ 52 RPM, pulsed DC power.

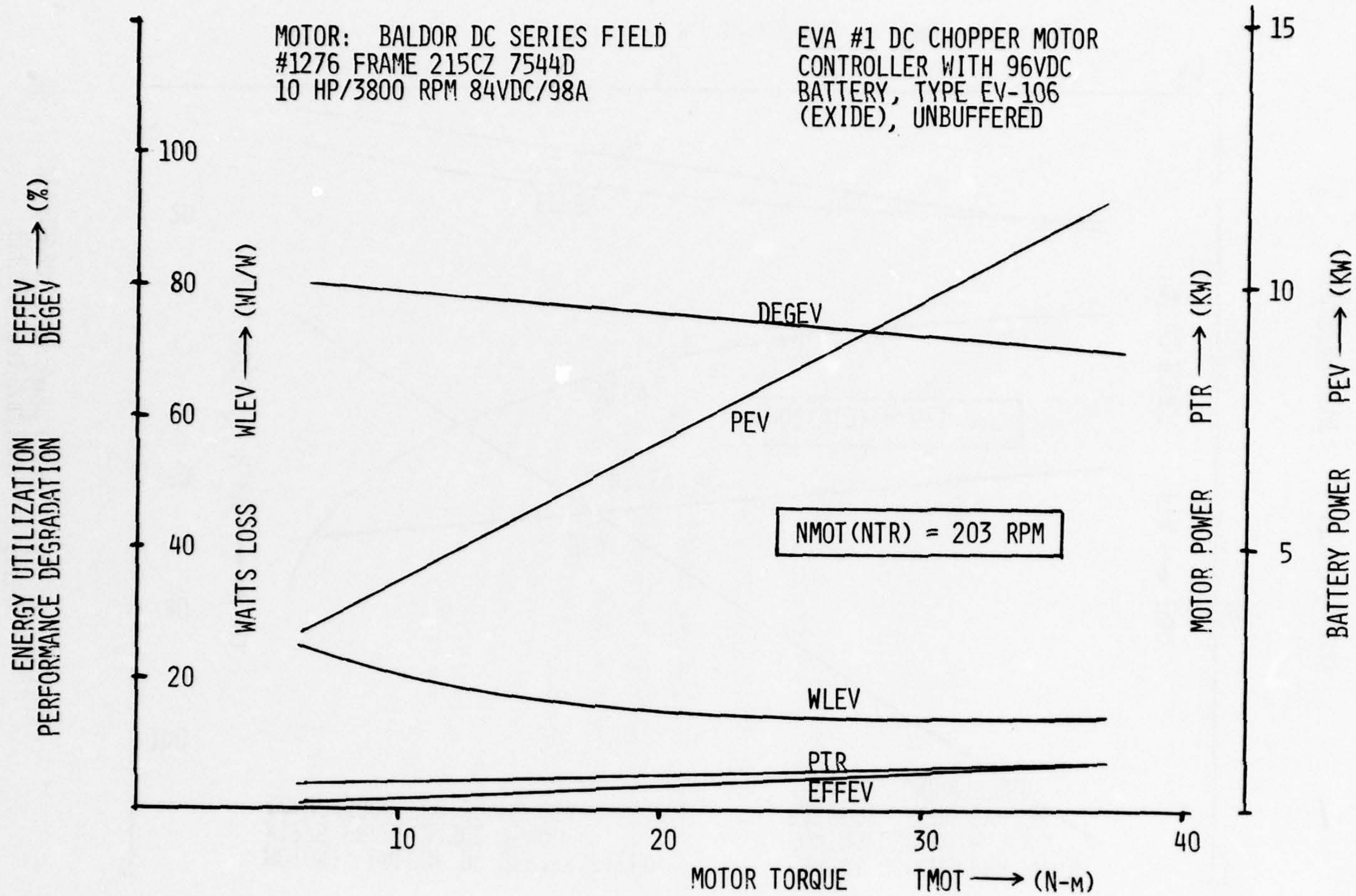


Figure 13.8B. System propulsion profile @ 203 RPM, pulsed DC power.

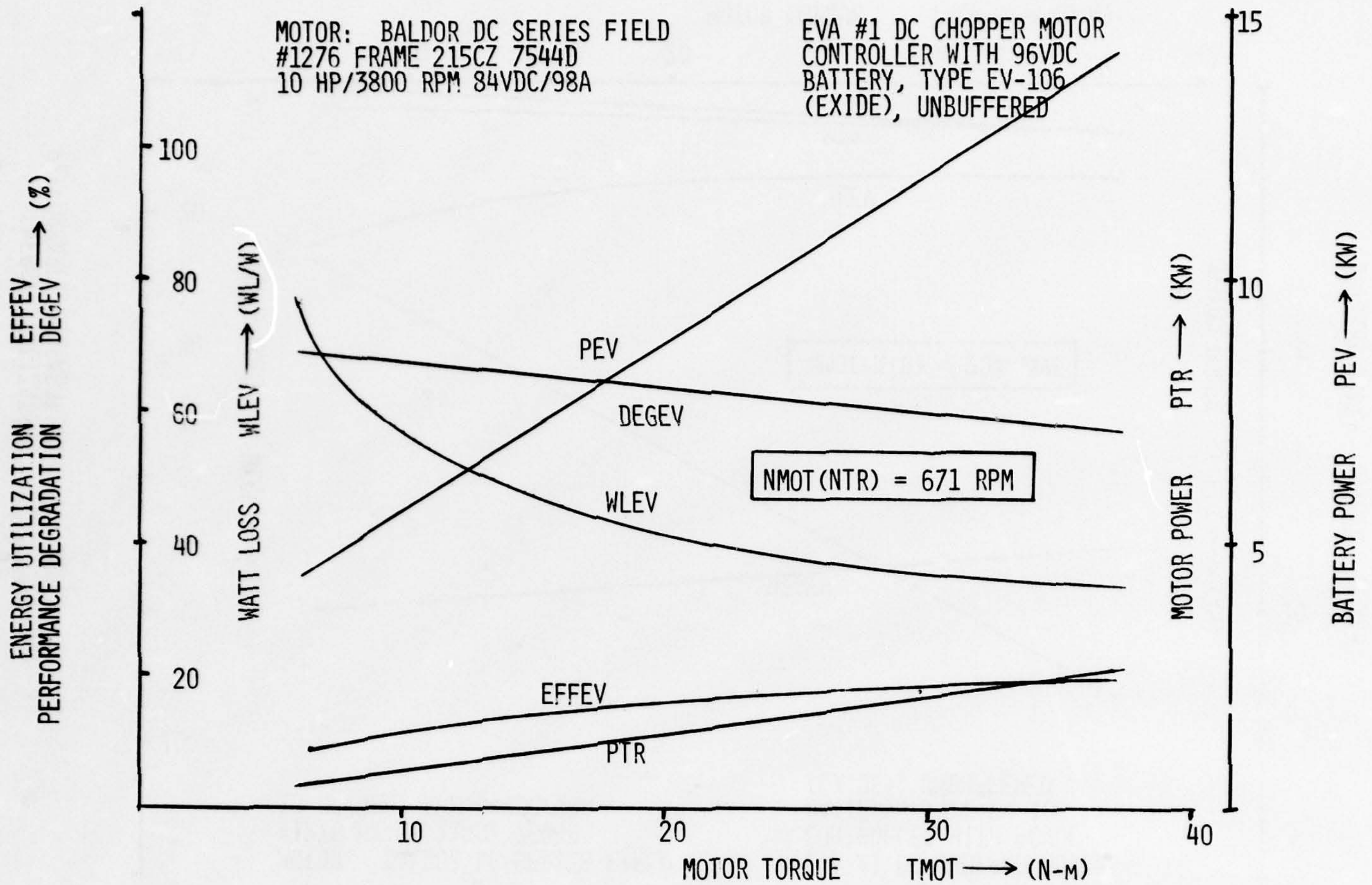


Figure 13.8C. System propulsion profile @ 671 RPM, pulsed DC power.

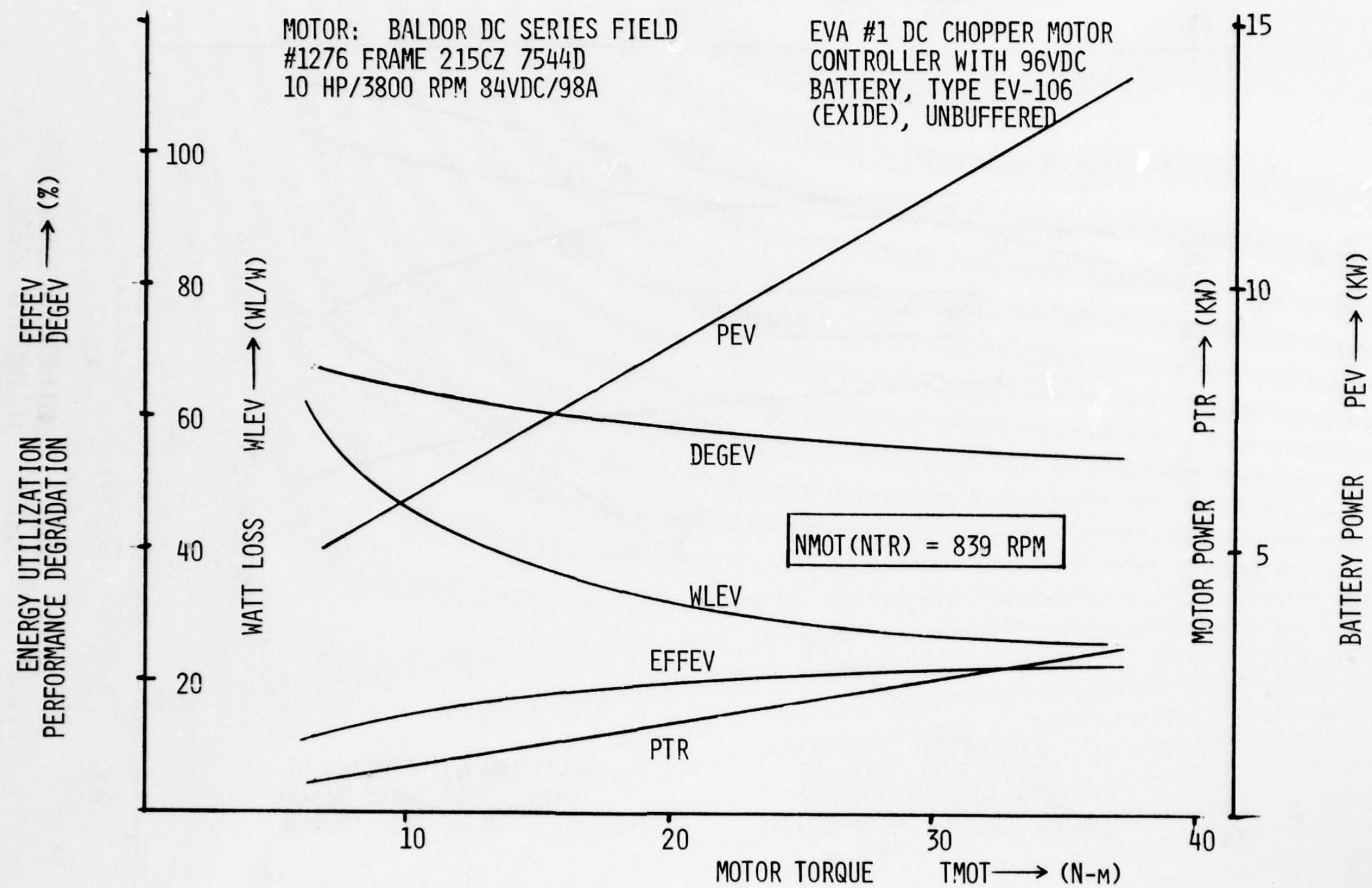


Figure 13.8D. System propulsion profile @ 839 RPM, pulsed DC power.

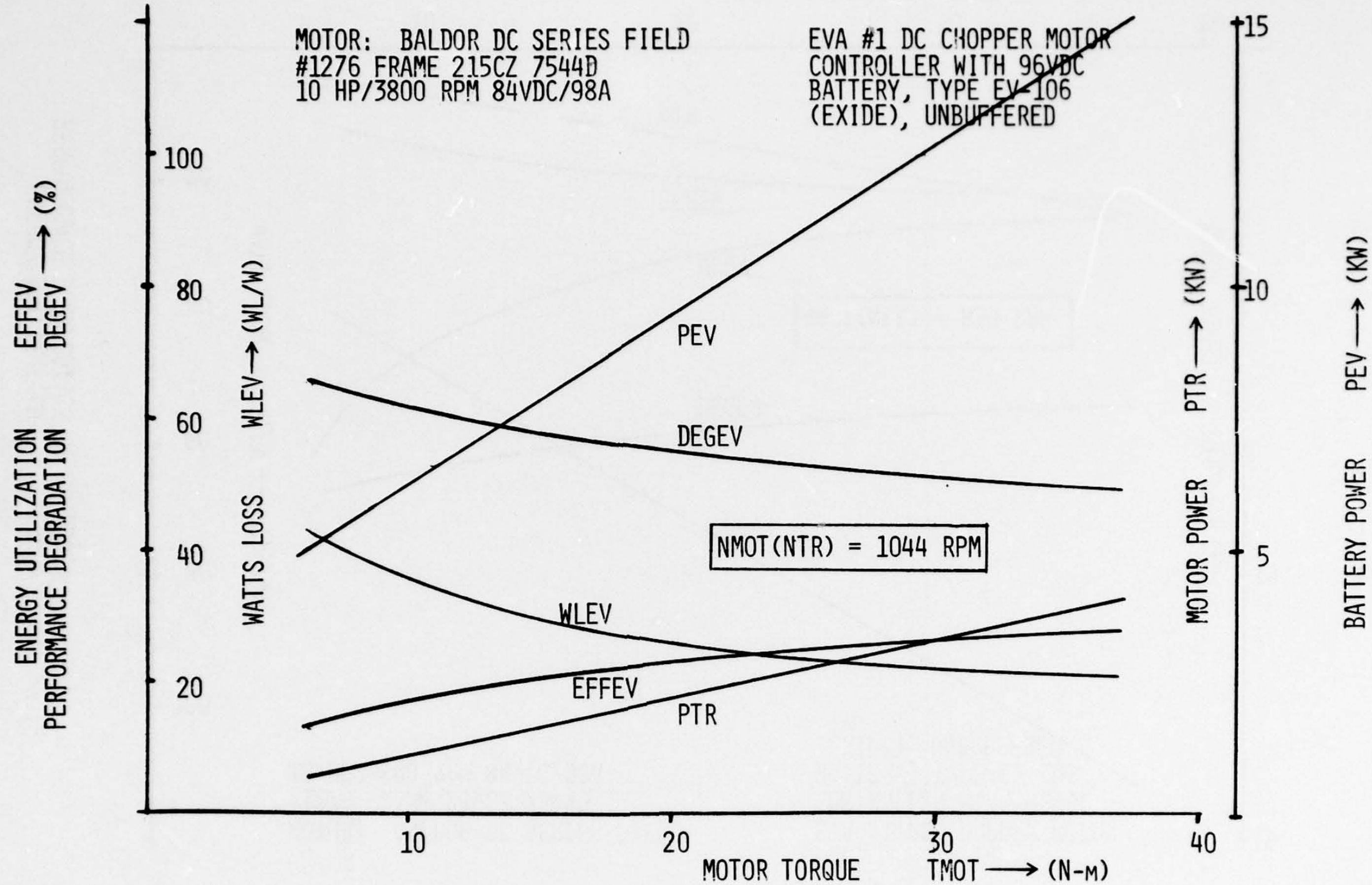


Figure 13.8E. System propulsion profile @ 1044 RPM, pulsed DC power.

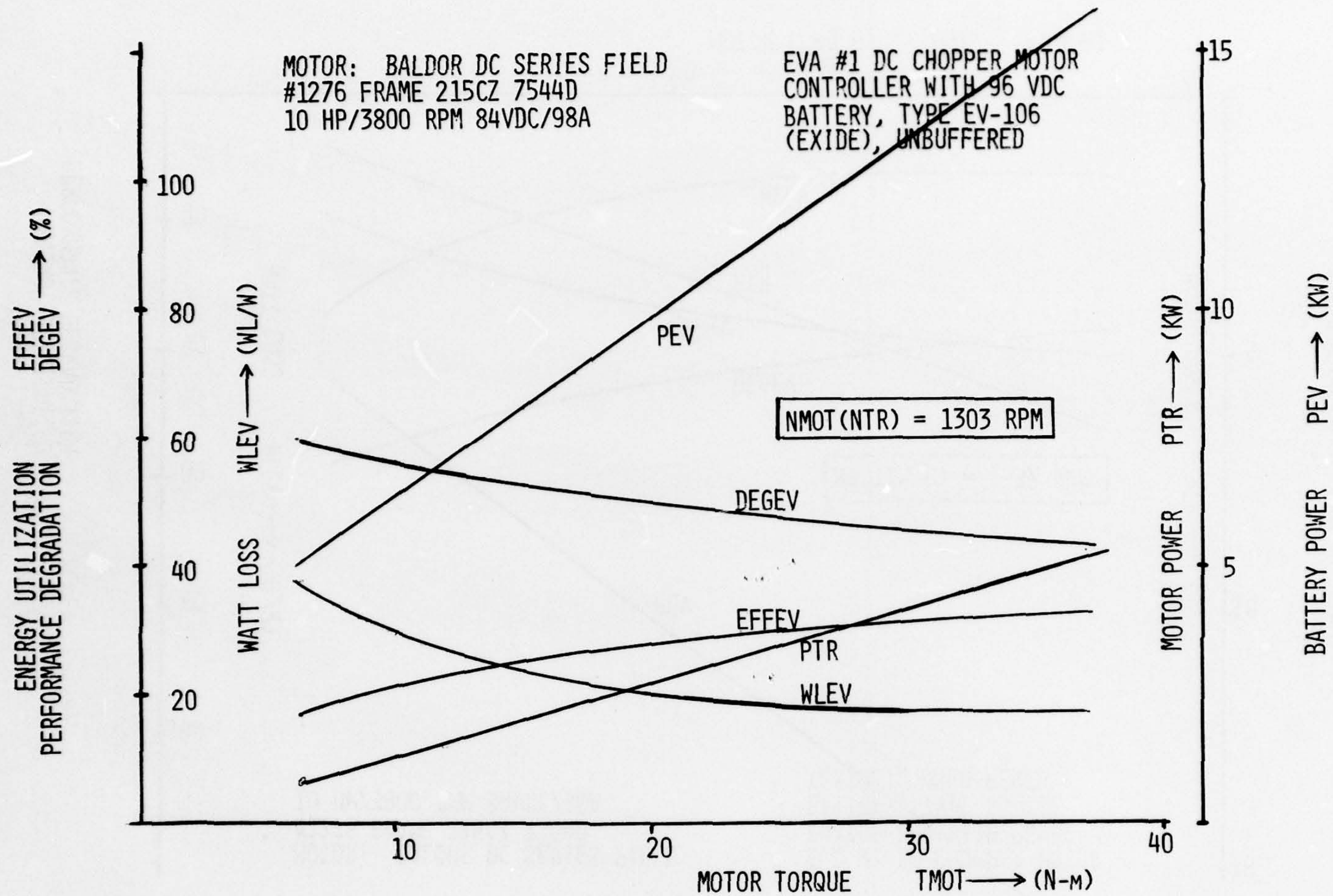


Figure 13.8F. System propulsion profile @ 1303 RPM, pulsed DC power.

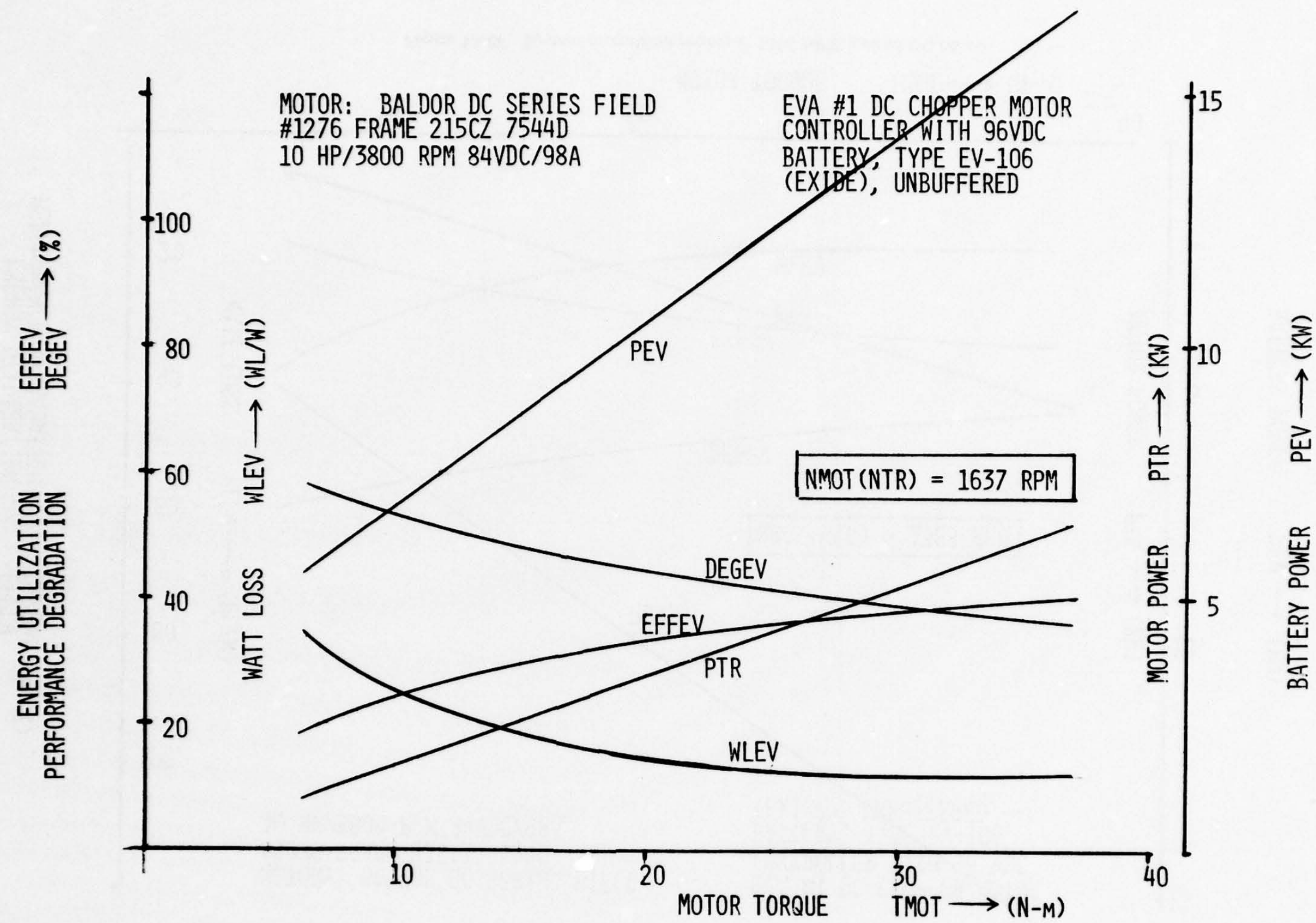


Figure 13.8G. System propulsion profile @ 1637 RPM pulsed DC power.

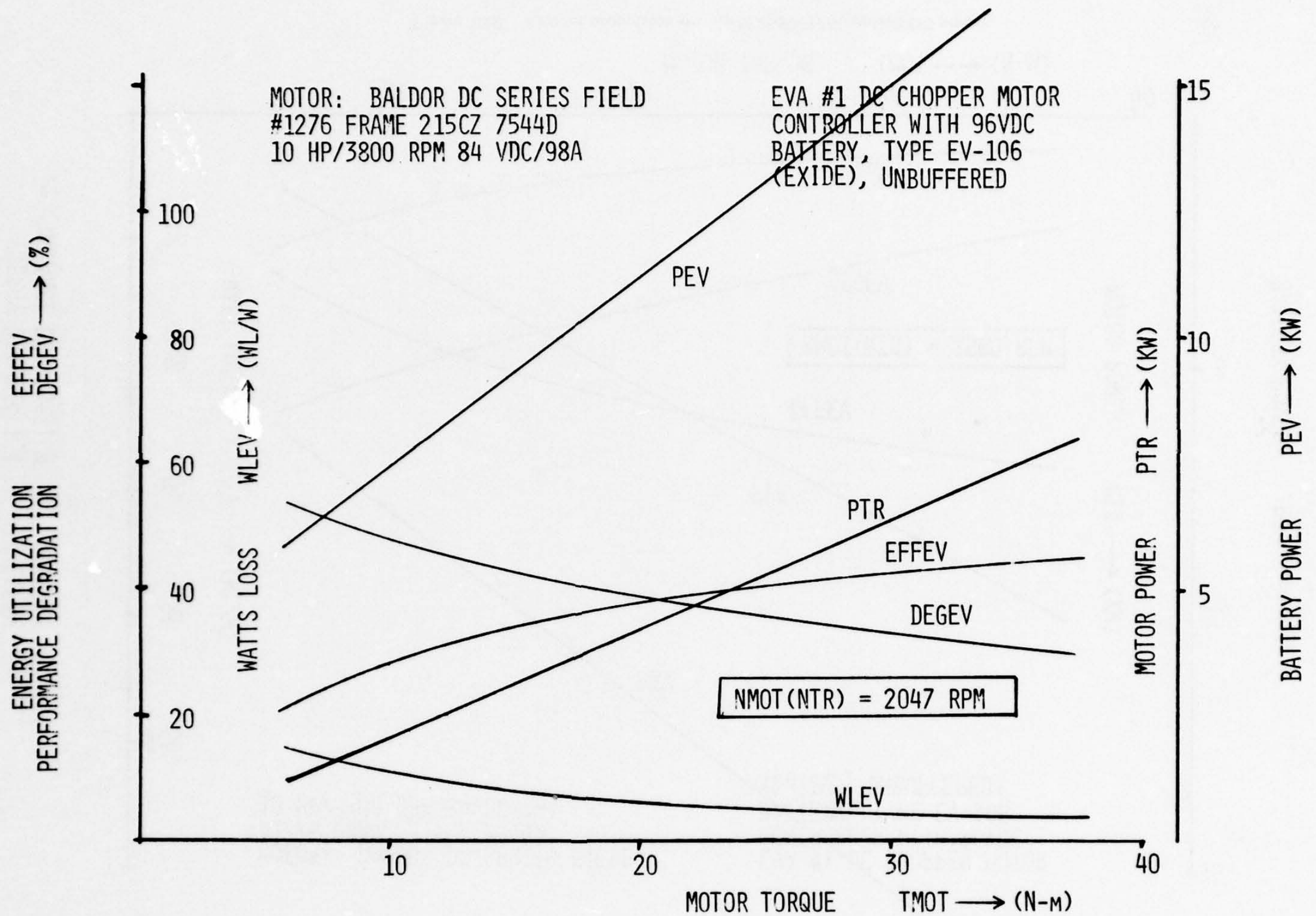


Figure 13.8H. System propulsion profile @ 2047 RPM, pulsed DC power.

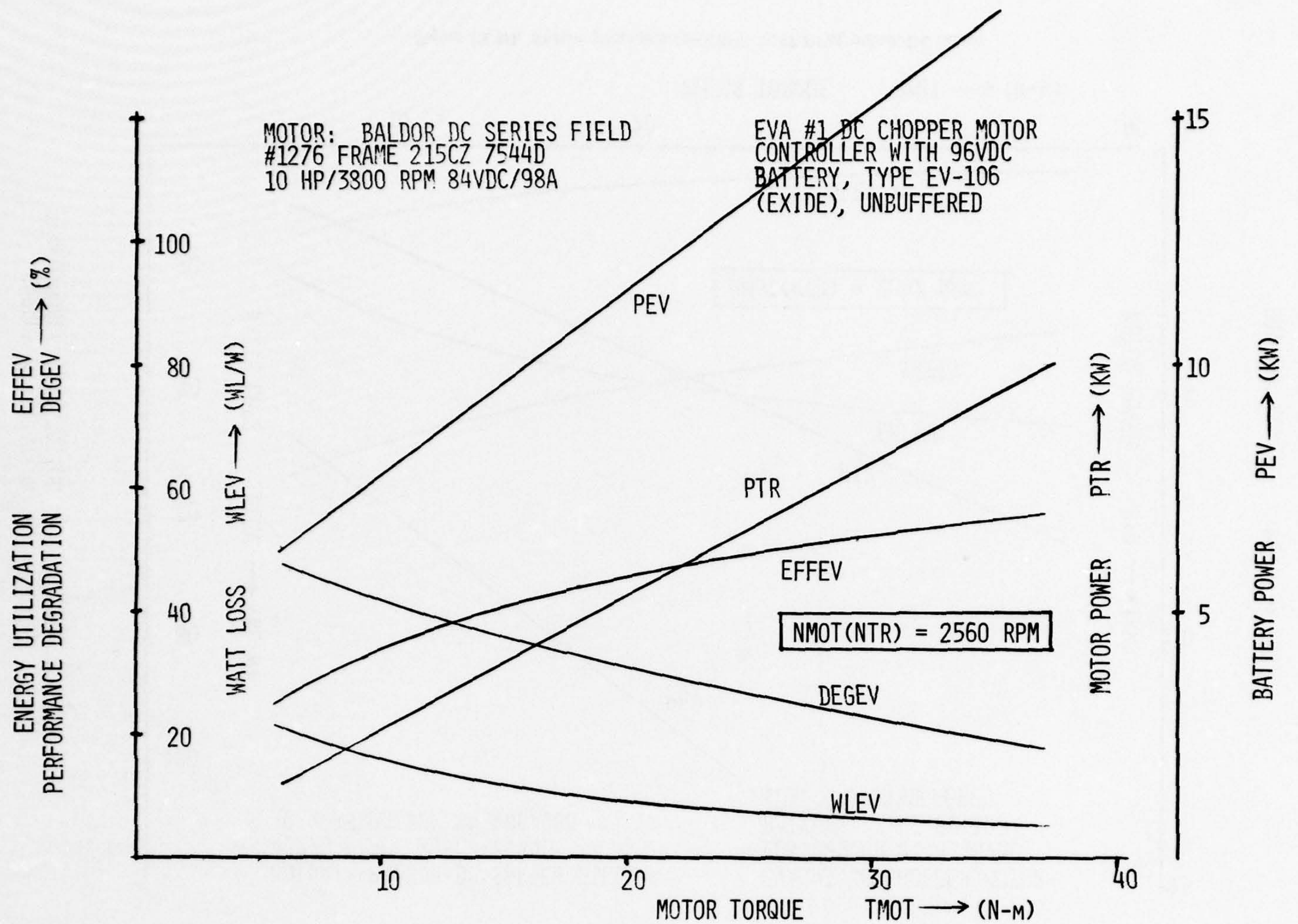


Figure 13.8I. System propulsion profile @ 2560 RPM, pulsed DC power.

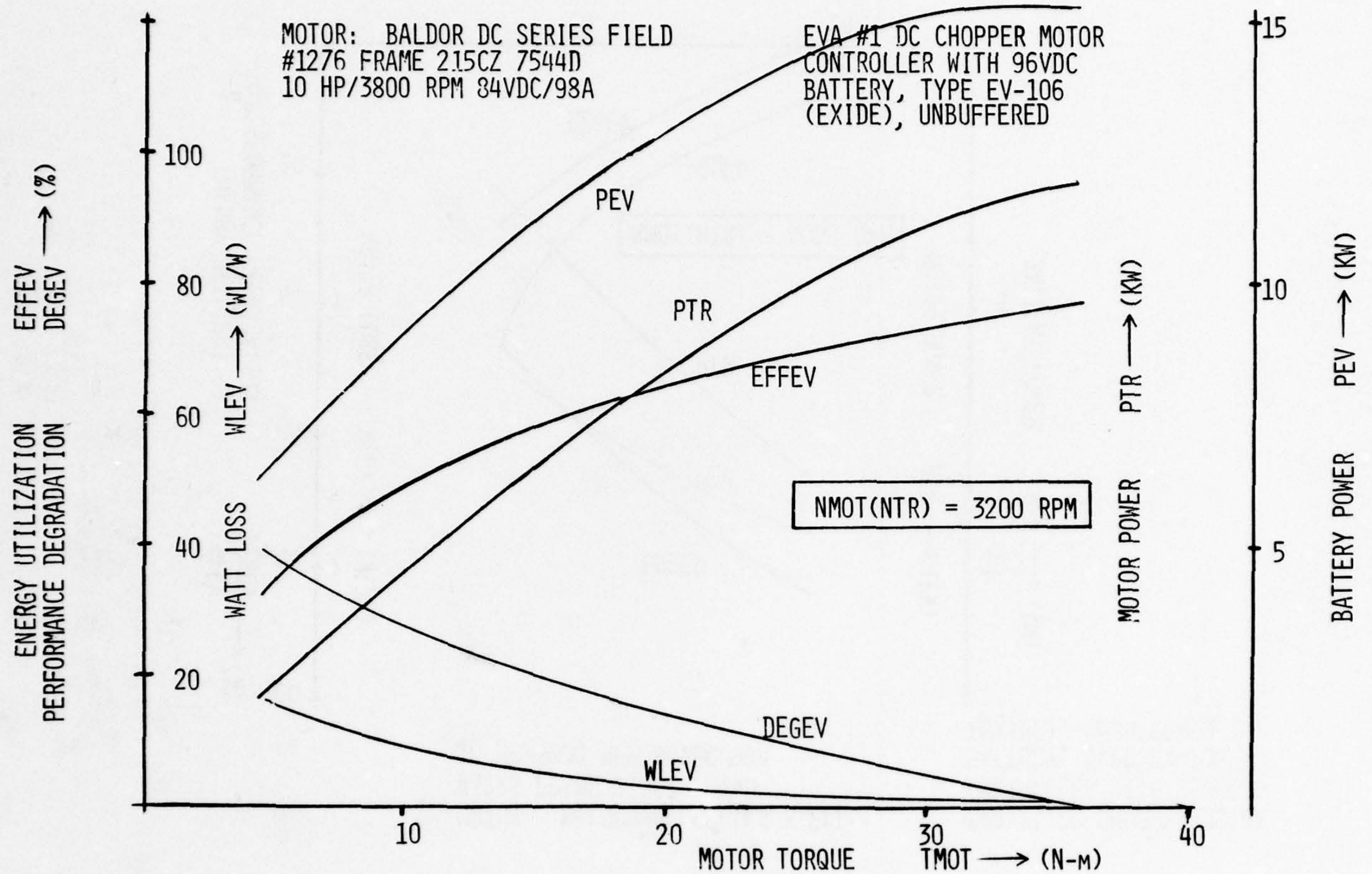


Figure 13.8K. System propulsion profile @ 3200 RPM, pulsed DC power.

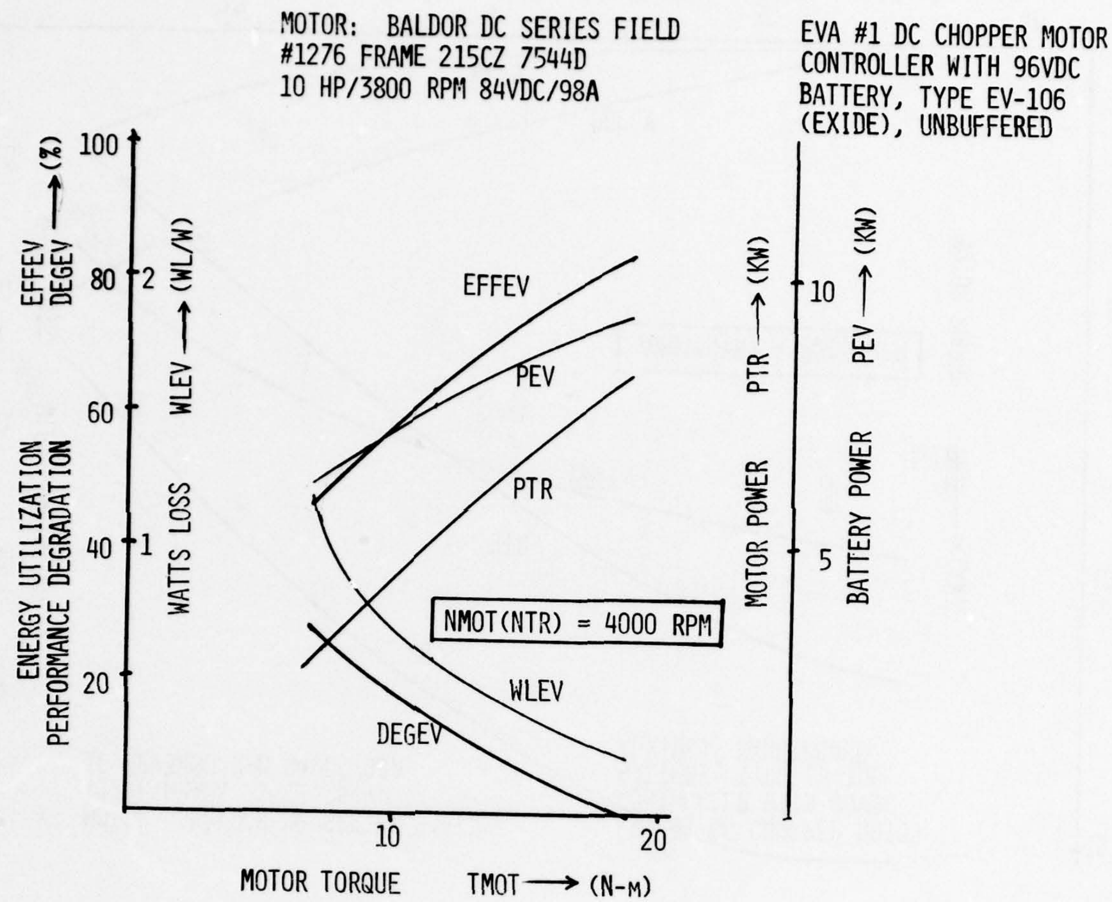


Figure 13.8L. System propulsion profile @ 4000 RPM, pulsed DC power.

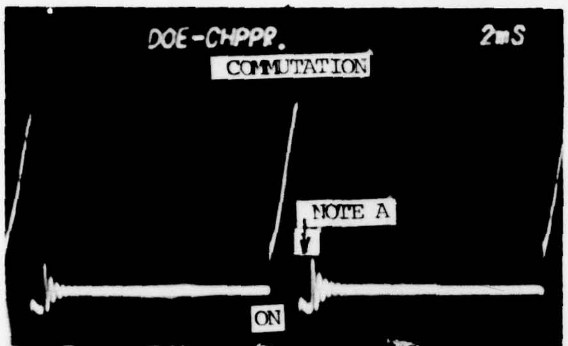


FIG. 14.1A: Battery current (IBAT)
IBAT = 100A/cm

NMOT ≃ 200 RPM
TORQUE ≃ 23 N-m
fc - 110 Hz

— 0

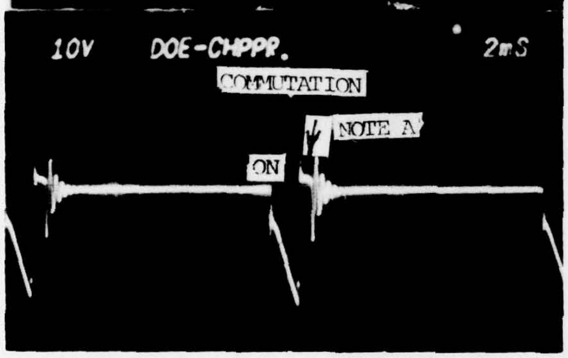
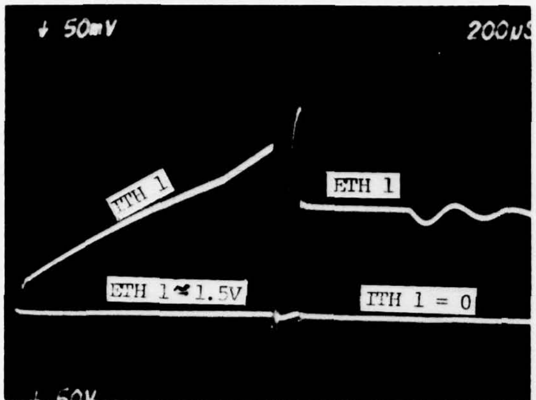


FIG. 14.1B: Battery ripple voltage (EBAT)
EBAT = 10V/cm

— 0

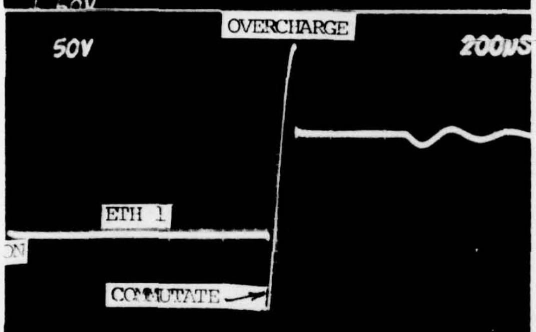
(+EBAT) ≃ 96VDC actual voltage

NOTE: Commutation of thyristor (TH1) completed, capacitor (C4) overcharges. Excess charge is subsequently returned to the battery causing its voltage to rise temporarily. Oscillatory transients are caused by interaction of line inductance and commutating circuit reactances (L) and (C4).



–0

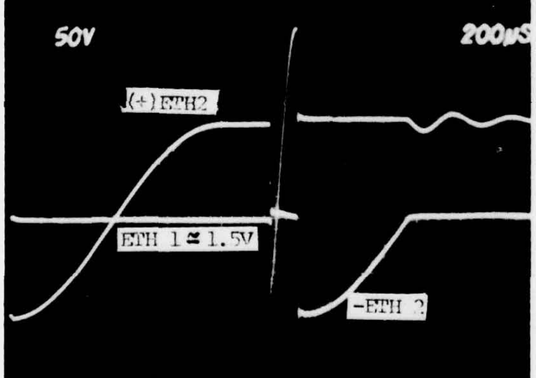
FIG. 14.2A: Superimposed ITH1 = 100A/cm and ETH1 = 50V/cm



ETH1

– 0

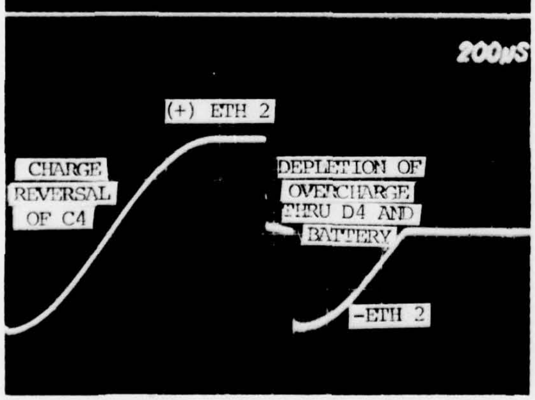
FIG. 14.2B: Thyristor (TH1) voltage ETH1= 50V/cm. After commutation capacitor (C4) overcharges temporarily to 2 x EBAT until current flow is reversed resulting in bleeding off excessive charge thru diode (D2). Return path is thru diode (D4).



–ETH1

– ETH2 = 0

FIG. 14.3A: ETH1 vs. blocking voltage of commutating thyristor (TH2). ETH2 = 50V/cm ETH1 = 50V/cm



- 0

FIG 14.3B: Blocking voltage of commutating thyristor (TH2) ETH2 = 50V/cm

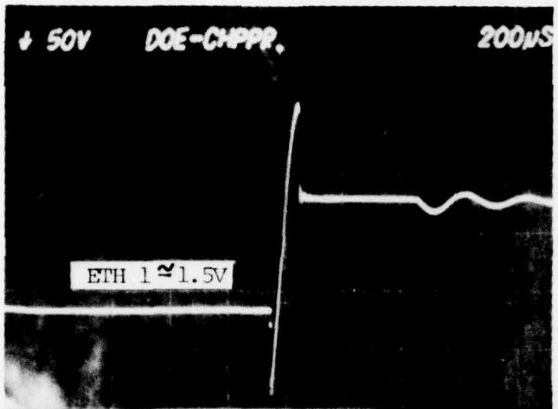


FIG. 14.4A: Thyristor voltage (ETH1). ETH1 = 50V/cm

ETH1

- 0

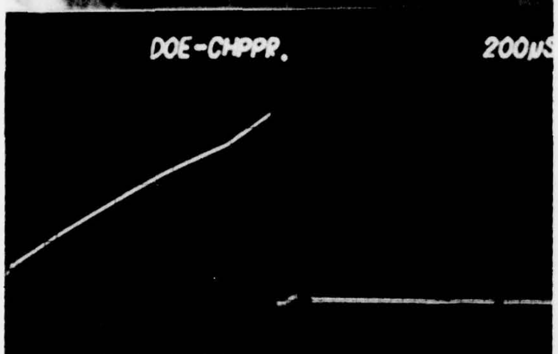


FIG. 14.4B: Thyristor current (ITH1) during power mode. Commutating impulse is suppressed - ITH1 = 100A/cm

ITH1

- 0

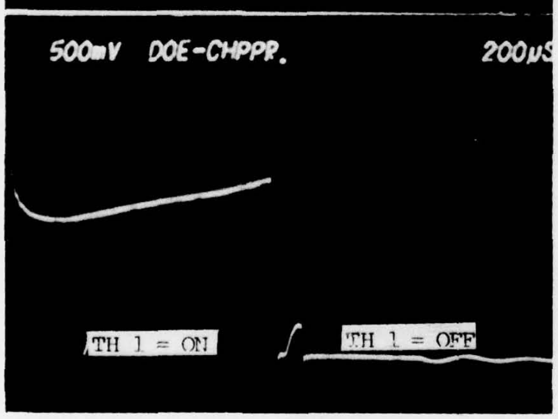


FIG. 14.4C: Thyristor on-voltage (ETH1 on). ETH1 is clamped above 10 volt amplitude.
ETH1 on = 0.5 V/cm

ETH1 on

- 0

Marginal anode breakover?

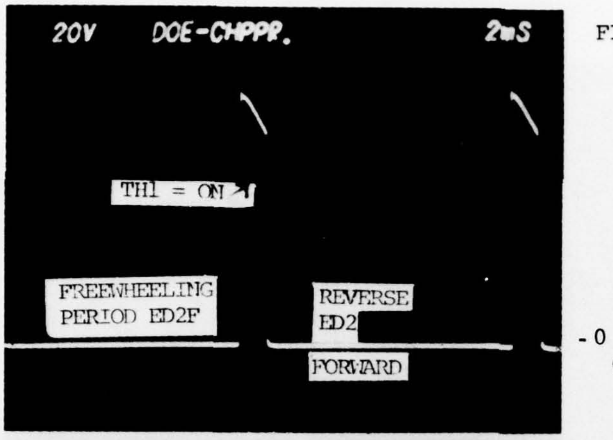


FIG. 14.5A: Forward and reverse voltage characteristics (ED2) of inverse by-pass diode (D2). Oscilloscope common terminal on cathode.
ED2 = 20V/cm

(+) EBAT = 20V/cm

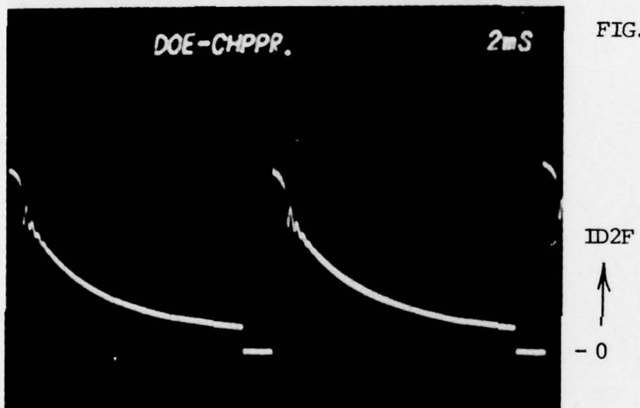


FIG. 14.5B: Freewheeling diode (D2) current (ID2F).

ID2F = 100A/cm

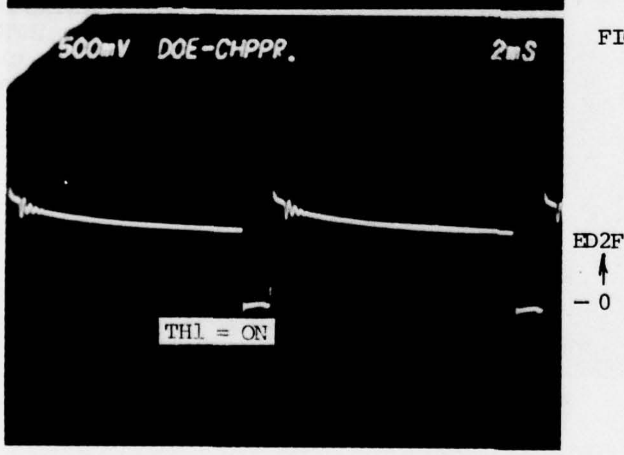


FIG. 14.5C: Forward conduction voltage (ED2F) of inverse by-pass diode (D2).

ED2F = 0.5V/cm

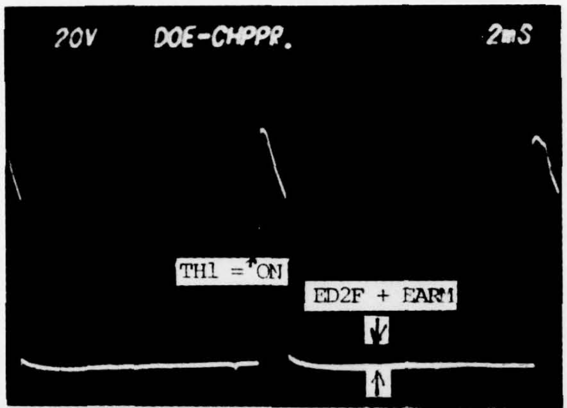


FIG. 14.6A: Voltage drop across dc motor series field (EFM). Common terminal of oscilloscope on anode of TH1. EFM = 20V/cm

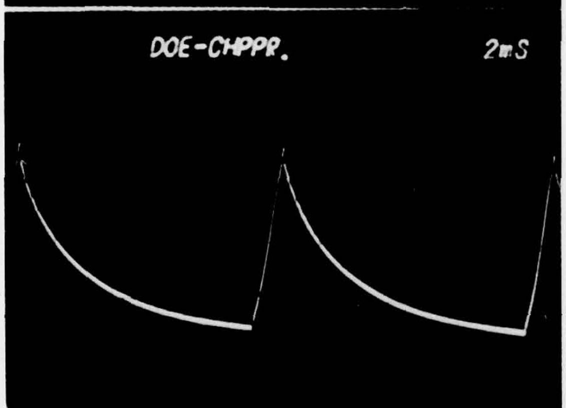


FIG. 14.6B: Motor current (IARM = ITH1 + ID2F). The relative low chopper frequency results in high ripple amplitude.

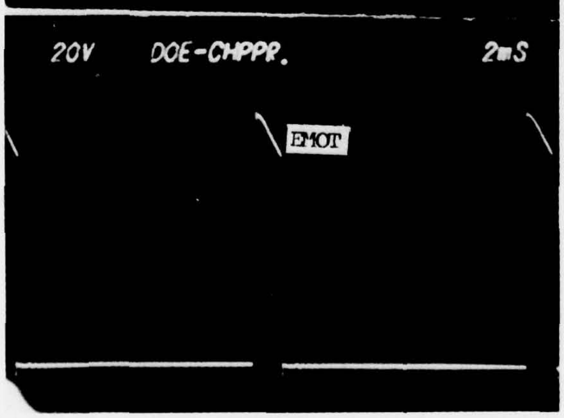
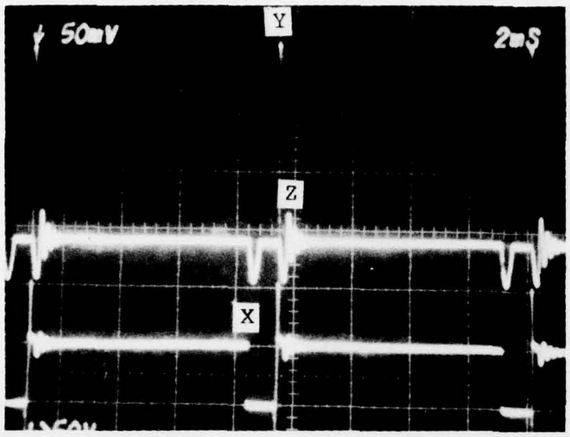


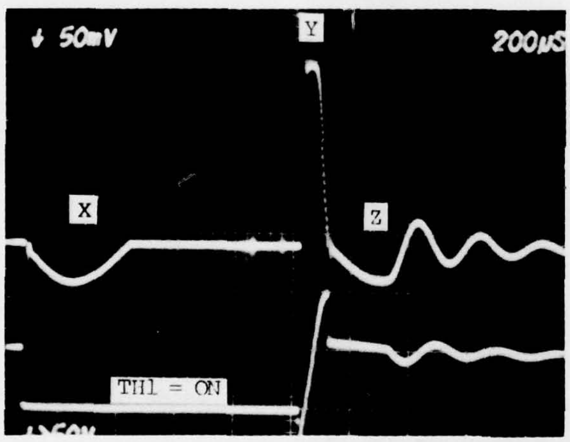
FIG. 14.6C: Motor voltage (EMOT). Common terminal of oscilloscope on anode of TH1. EMOT = 20V/cm



— 0

— 0

FIG. 14.7A: Commutation.
Upper trace: capacitor current (IC4)
X: TH1 = on, charge reversal of C4.
Y: TH1 is commutated thru TH2
Z: Return of excess charge in C4 to battery thru D2.
IC4(Inverted) = 100A/cm
Lower trace: thyristor voltage (ETH1). Common terminal of oscilloscope is on common of current shunt (RSH8).
ETH1(Inverted) = 50V/cm



— 0

— 0

FIG. 14.7B: Commutation.
Expanded scale of Fig. 14.7A.
Upper trace:
IC4 (Inverted)
IC4 (Inverted) = 100A/cm
Lower trace:
ETH1 (Inverted)

ETH1 (Inverted) = 50V/cm

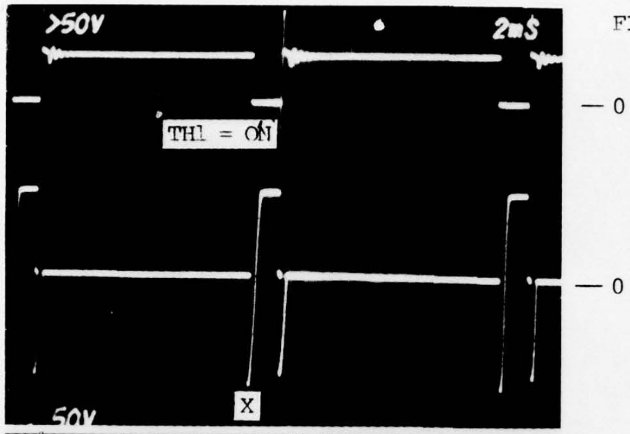


FIG. 14.8A: Upper trace:
ETH1 100V/cm

Lower trace:
ETH2 = 50V/cm

X: TH1 = on, charge reversal in C4.
Y: Commutation of TH1 thru TH2.
Z: Return of excess charge in C4 to battery

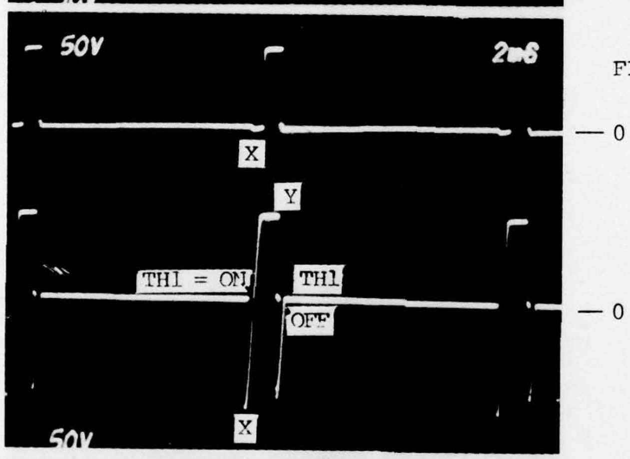


FIG. 14.8B: Upper trace:
ED4 = 50V/cm

Lower trace:
ETH2 = 50V/cm.
Oscilloscope common terminal on cathode of TH2.

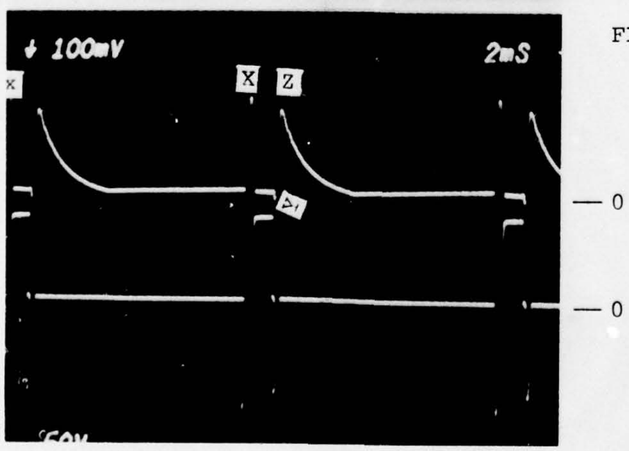


FIG. 14.8C: Upper trace:
ID4 = 40A/cm

Lower trace:
ETH2 = 50V/cm

FIG. 14.9: Expanded time scale of events shown previously.

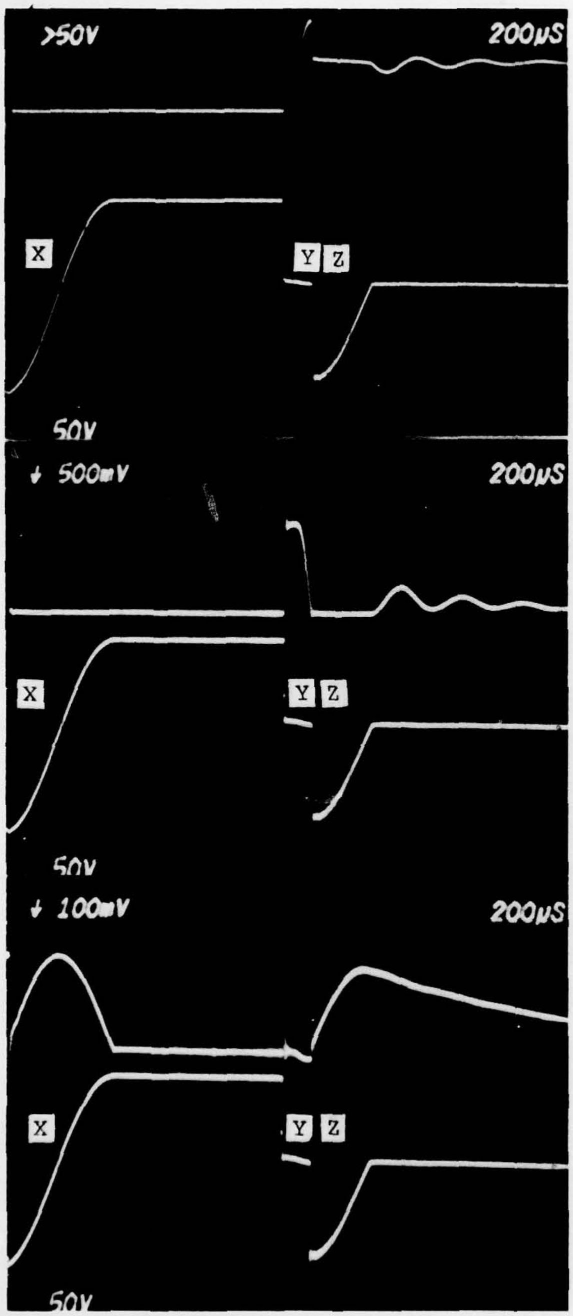


FIG. 14.9A:

- 0 ETH1 ~ 100V/cm

ETH2 = 50V/cm

— 0

X: TH1 = on, charge reversal in C4
Y: Commutation of TH1 thru TH2
Z: Return of excess charge in C4 to battery.

FIG. 14.9B:

ITH2 = 200A/cm

— 0

ETH2 = 50V/cm

— 0

FIG. 14.9C:

ID4 ≅ 40A/cm

— 0

ED4 = 50V/cm

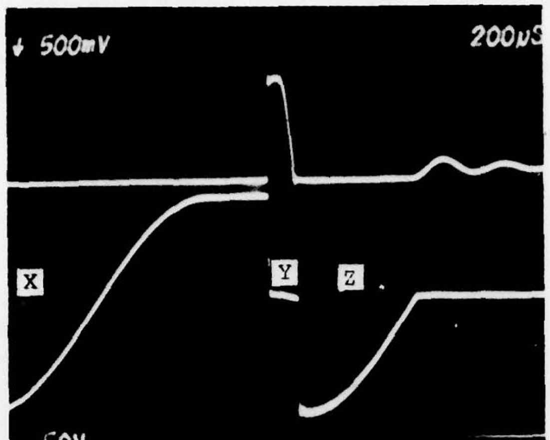


FIG. 14.10A: Expanded time scale of Fig. 14.10B.
ITH2 = 200A/cm

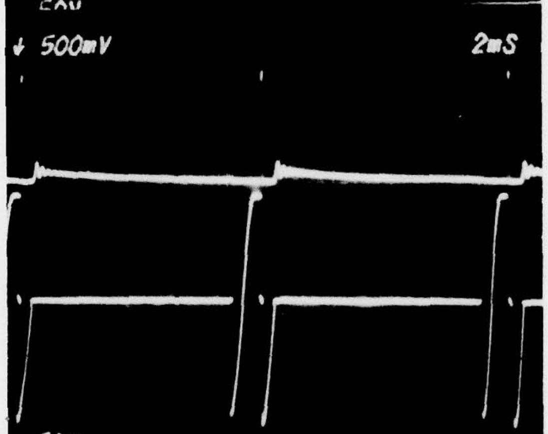


FIG. 14.10B:
ITH2 ≃ 200A/cm

ETH2 = 50V/cm

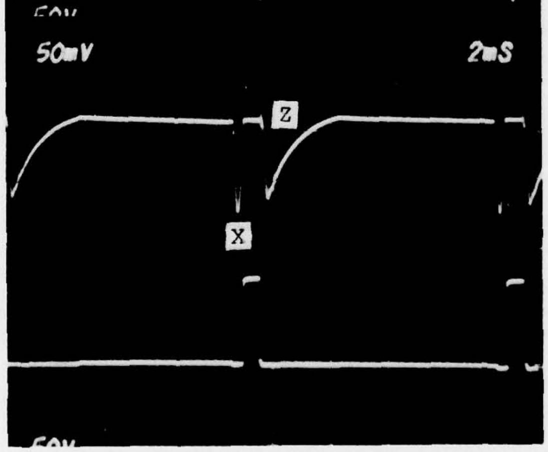


FIG. 14.10C:

ID4 = 40A/cm

E04 (Rev)

(IARM) contains a very high ripple content. This causes additional heat losses in the machine because of additional resistive losses and magnetic losses. It is possible to reduce the ripple by either increasing chopper frequency from its present typically 110 Hertz repetition rate, or by increasing motor inductance. As shown in Figure 14.11, ripple content of the motor current is still excessive at 1000 RPM motor speed, and for that matter was excessive for most of the speed and load profile.

XV. BATTERY ENERGY TRANSFER EFFICIENCY TEST*

The testing of the Prestolite battery, Model 9915-X, Serial No: 001639, 75 A @ 110 minutes, 6 V DC (nominal), was limited to a single temperature test, whereby the electrolyte temperature fluctuated typically between 13½°C (56°F) and 21°C (70°F). Emphasis was placed on conditions of minimum gasing during charge and the determination of END-OF-DISCHARGE. End-of-discharge was considered at the point of inflection of the instantaneous power curve, e.g.: a power level of $PABAT_o$ $\sqrt{2}$ for a constant and resistive load profile. This corresponded to a cell voltage of 1.43 V DC.

For a new battery the degradation of available output power between the limits $PABAT_o$ and $PABAT_o/\sqrt{2}$ coincided with the available battery capacity of 130 AH @ IBAT = 50 A DC. Understandably, the available battery capacity progressively decreased with increased load demand and was typically 105 AH @ 75 A DC and 90 AH @ 125/150 A DC current amplitude.

Discharge as well as recharge cycles were conducted at 50/75/100/125/150 A DC constant current levels. During recharge, constant current was maintained until gasing occurred. At this point the average current amplitude was reduced automatically such that the established rate of gasing was not exceeded. The chronological charge and discharge data for this test series are shown in Table 11, while Figures 15.1 through 15.3 show the sustainable battery charge current (IBAT) as function of time, energy input (JBAT) and transfer requirement as function of charge current, as well as calculated energy transfer efficiency (ηBAT).**

XVI. EMI AND SOUND LEVEL TEST

1. **Electromagnetic Interference (EMI)** was measured to determine the peak values being emitted from the vehicle drive motor and associated circuitry under the following load conditions:

a. 50 A current draw (IBAT AVG), transmission in neutral. Data are plotted in Figure 16.1.

* Although the testing of energy transfer efficiency was limited in scope, it is believed that the described method makes it possible to generate repeatable test results and to fully characterize any battery line in a future test program. With this method it will be possible to adequately define usable battery capacity as a function of temperature, load current and aging. The result of such testing would yield a family of curves which could be applied generally to this type of battery with reasonable confidence.

** The author is well aware that advanced charge methodologies which impact the chemical reaction of the battery, can extend the life of the battery between recharges. However, these methods will be hardly available to the present-day consumer. Thus, the potential consumer's daily battery charge routine will remain unaffected. Furthermore, regardless of the method chosen to recharge the battery, including consideration of coulombic efficiency, the basic question still remains what is the energy requirement to charge a battery in order to expend a set quantity of available energy at a defined rate of discharge. Thus, in terms of actual field requirements, the proposed charge/discharge monitoring mechanism is considered quite valid and practicable.

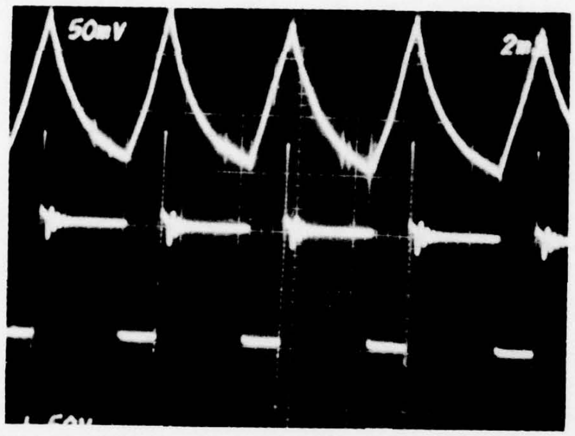


FIG. 14.11:
IARM = 100A/cm

- 0

ETH1 = 50V/cm
Common terminal of oscilloscope on anode of TH1.

- 0

NMOT ≃ 1000 RPM

Table 11. Chronological Charge and Discharge Data.

LINE ITEM	PROJECT	TIMING Initial START	TIMING Data POINT	TIMING STOP	G.P.	To GAS & TAPER on CHG. / DISCHG. to INFLECT. HR.-Init. Start	AMP-HRS	WATT-HRS
1	50-AMPERE CHARGE	02:34:PM 11:15:AM 10:01:AM	05:22:30	06:32:PM 11:23:PM 10:32:AM	0.5"	02:48:30	139.90	931.20
2	50-AMPERE DISCHARGE	11:21:AM 10:29:30 11:13:PM 02:13:PM	01:59:PM	03:06:PM 11:05:AM 11:38:PM 03:00:PM		02:38:00	132.25	755.2
3	100-AMPERE CHARGE	12:40:PM 12:48:PM	01:40:PM	12:45:PM 11:25:PM	0.4"	00:52:00	94.74	678.4
4	100-AMPERE DISCHARGE	10:04:AM 05:20:PM	11:03:AM	11:46:AM 05:32:PM		01:01:00	100.6	544.0
5	75-AMPERE CHARGE	05:41:PM	07:10:PM	11:25:AM	0.9"	01:29:00	110.54	754.6
6	75-AMPERE DISCHARGE	10:00:AM	11:24:30	12:00:30		01:24:30	105.11	584.8
7	125-AMPERE CHARGE	03:48:PM 11:00:AM 02:03:PM	11:30:AM	04:00:PM 11:50:AM 06:32:PM	1.8"	00:30:00	70.36	560.0
8	125-AMPERE DISCHARGE	03:07:PM	03:52:45	04:08:00		00:45:15	91.98	494.8
9	150-AMPERE CHARGE	04:18:PM 05:35:PM	04:44:00	05:35:PM 11:19:PM	0.5"	00:26:00	65.88	451.2
10	150-AMPERE DISCHARGE	09:21:AM	09:59:AM	11:00:AM		00:38:00	96.84	487.2
11	TOTAL							

Table 11. Chronological Charge and Discharge Data (Cont'd)

LINE ITEM	PROJECT	ACCUMULATION Hours	AMPS-HRS	WATT-HRS	TOTALS (From initial starts) Hours	AMPS-HRS	WATT-HRS
1	50-AMPERE CHARGE	03:58:00 12:08:00 00:31:00	166.70 51.55 0.70	1144.8 473.2 12.8	16:35:00	+ 218.95	+ 1630.8
2	50-AMPERE DISCHARGE	03:45:00 00:36:00 00:25:00 00:47:00	165.73 10.12 2.00 6.10	818.4 48.0 12.0 26.4	05:33:00	- 183.45	- 904.8
3	100-AMPERE CHARGE	11:45:00	196.12	1523.2	11:45:00	+ 196.12	+ 1523.2
4	100-AMPERE DISCHARGE	01:42:00 00:12:00	135.94 18.26	624.0 92.8	01:54:00	- 154.20	- 716.8
5	75-AMPERE CHARGE	05:44:00	159.54	1145.6	05:44:00	+ 159.54	+ 1145.6
6	75-AMPERE DISCHARGE	02:00:30	131.7	640	02:00:30	- 131.70	- 640.0
7	125-AMPERE CHARGE	00:12:00 00:50:00 04:29:00	15.72 104.12 45.84	99.6 758.4 316.8	05:31:00	+ 165.68	+ 1174.8
8	125-AMPERE DISCHARGE	01:01:00	109.00	515.2	01:01:00	- 109.00	- 515.2
9	150-AMPERE CHARGE	01:17:00 05:44:00	107.72 122.44	777.6 235.2	07:01:00	+ 230.16	+ 1012.8
10	150-AMPERE DISCHARGE	01:39:00	140.6	566.4	01:39:00	- 140.6	- 566.4
11	TOTAL				58:51:00	+ 251.5	+ 3144.0

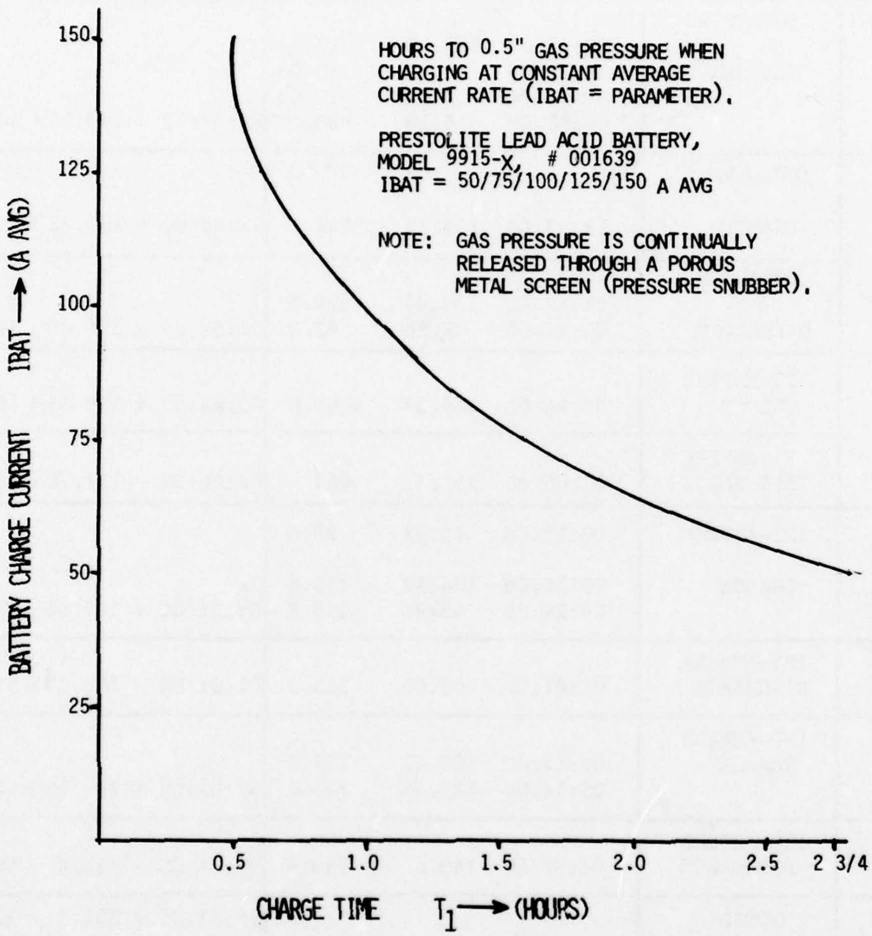


Figure 15.1. Battery maximum charge current vs. time prior to gasing.

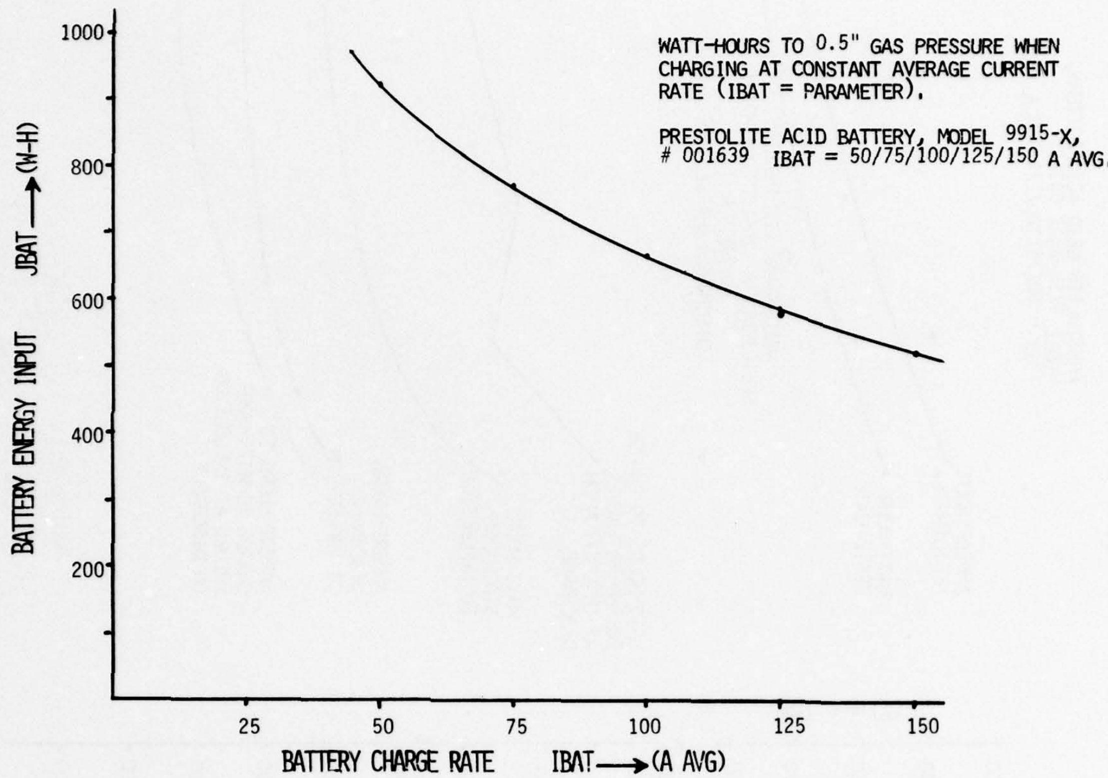


Figure 15.2. Battery energy input vs. charge rate.

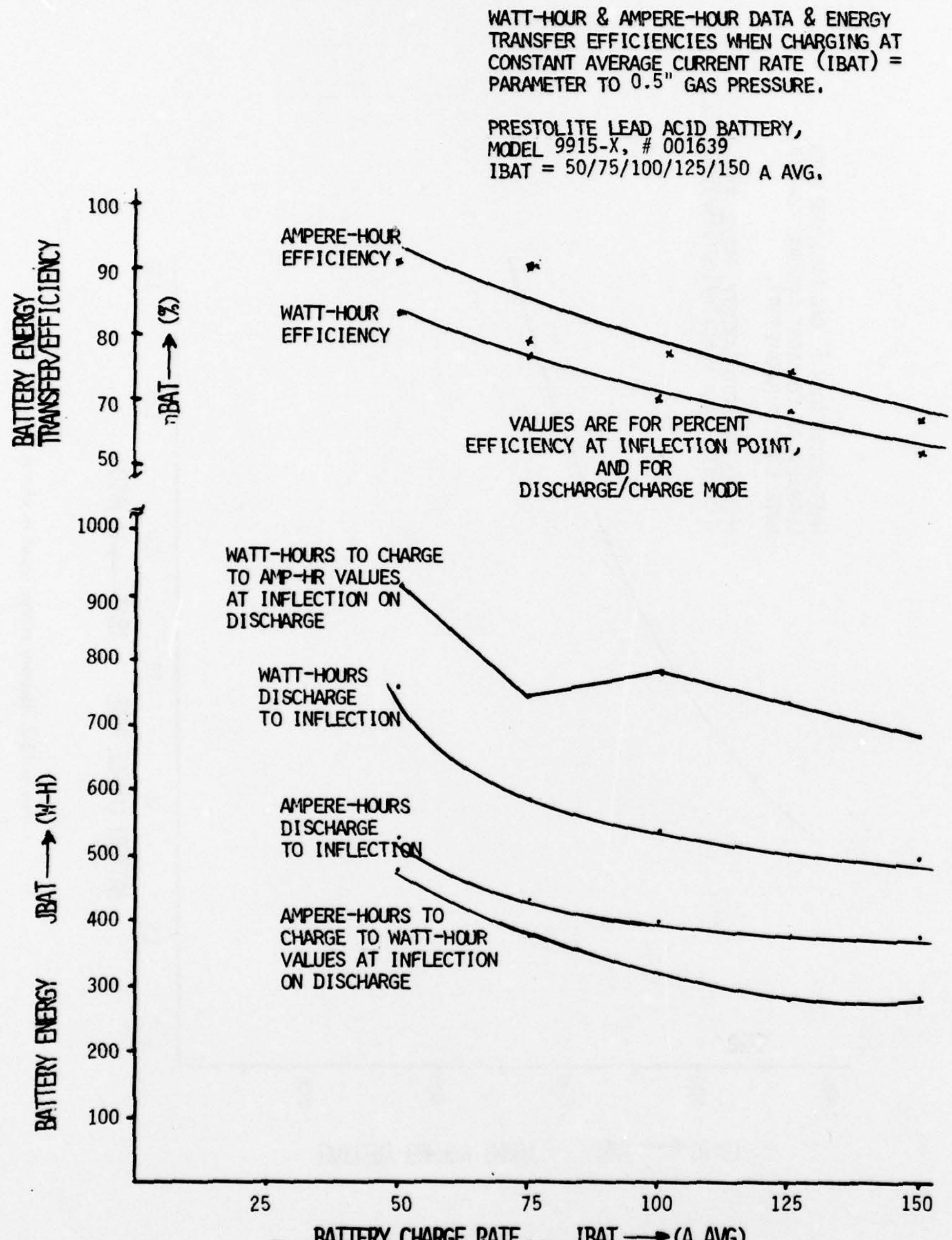


Figure 15.3. Battery discharge/charge efficiency.

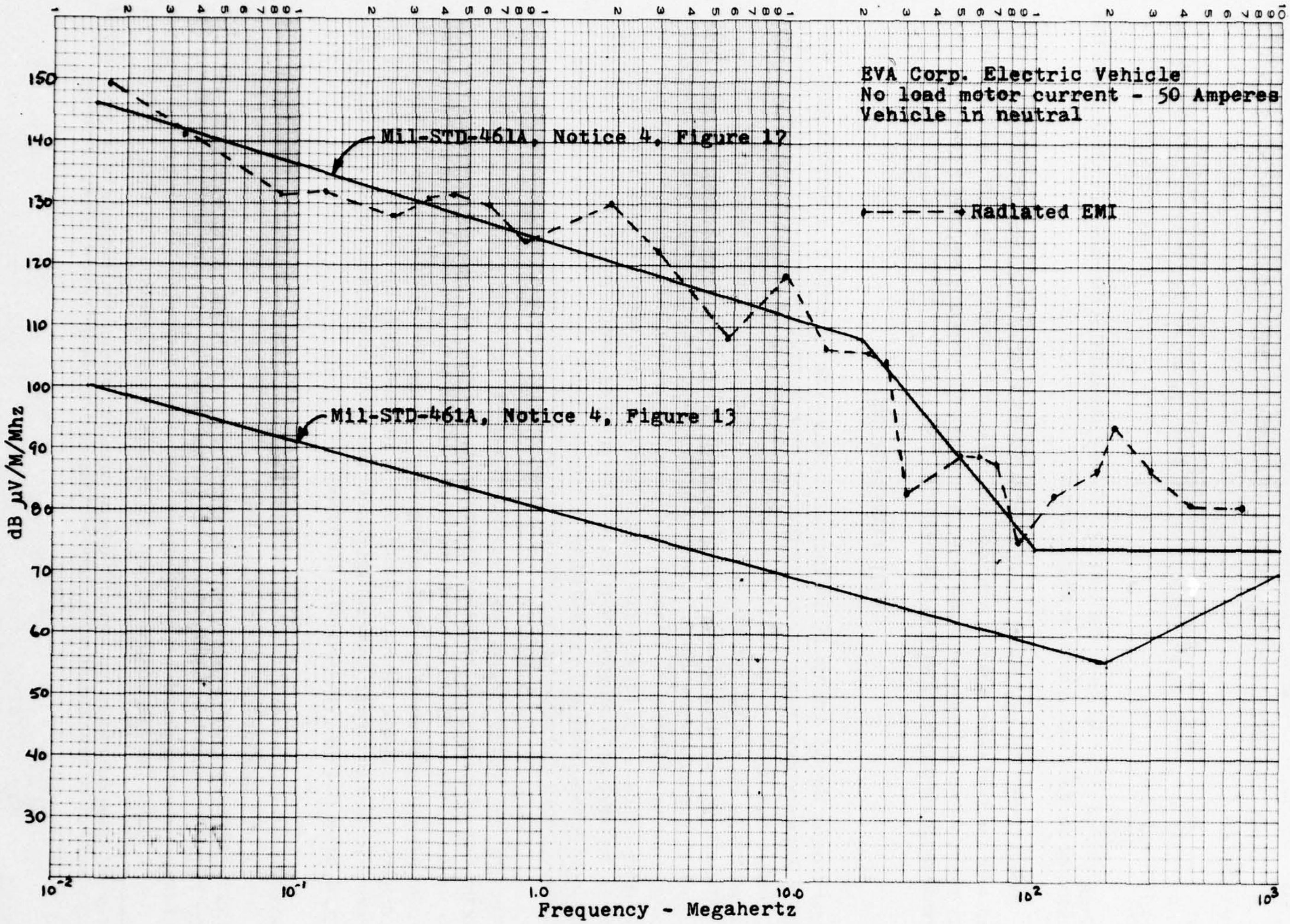


Figure 16.1. EMI test, no load.

b. 50 A current draw (IBAT AVG), transmission in Drive mode, brakes locked, Data are plotted in Figure 16.2.

c. 200 A current draw, transmission in Drive mode, brakes locked. Data are plotted in Figures 16.3 and 16.4.

The tests, conducted in the MERADCOM EMI Test Facility, showed that the radiated emissions from this vehicle exceeded the specification limits at all conditions.*

2. **Sound Level.** The operational Sound Level of the EVA Metro Sedan was considered low when compared with the road noise which is generated during rush hour traffic. Tests were conducted in the stationary mode, shown in Figures 16.5 and 16.6, as well as in the driving mode. The results of the tests in the driving mode are shown in Figure 16.7 and Table 12.

XVII. CONCLUSIONS

Power transfer through control of the conduction duty cycle by virtue of a constant pulse width and variable frequency gate trigger rate of the thyristor in a dc to dc motor controller, typically 30 to 500 Hz, yields a large ripple current in the dc motor over a wide speed and torque load range. This characteristic is generic to the control principle and describes typically 90% of all dc choppers used presently in both lift trucks and similar material handling equipment. The ripple current generates a large RMS/Average current amplitude ratio which is responsible for excessive motor heating and for considerable degradation of motor performance. To maintain a constant dc current in the motor, the peak amplitude of the pulsating current in the battery must increase steadily as motor speed decreases accompanied by a reduction in the chopper conduction duty cycle. The pulsating current amplitudes contribute toward more and more generation of heat in the battery as well and thus to excess dissipation of its energy. To minimize these losses it is of advantage to utilize the battery in the continuous dc current mode.

Generically, the class of chopper motor controllers which utilize variable pulse duration modulation to control the flow of energy from the battery to the motor, combined with a higher frequency pulse repetition rate, typically 400 to 2000 Hz, are the preferred means to reduce the ripple current in the motor. Such system can also make use of an energy storage filter between the controller and the battery in a way that a complete instantaneous current transformation is attainable from the usually higher voltage, low current source to the high current, lower voltage motor. This in turn reduces power losses, particularly at low motor speed, below measured values stated in this report.

The use of the data acquisition system made possible the high resolution testing of this electric propulsion drive at high measurement speeds heretofore not possible at this facility. Up to 36 data points were recorded within a measurement interval of typically 20 to 30 seconds, whereby both DC and RMS data were logged in sequentially within a few seconds. It has been our experience that the Average or DC values of measured motor parameters in conjunction with the dc chopper, or any other pulsed dc power source, closely match the data attained during the initial motor performance test when powered by a

* Though not available at this facility, it is believed that the noise and interference specifications issued by the FCC are closely patterned after MIL Specifications, or vice versa. Thus, the emissions generated by this vehicle are considered excessive under any circumstance.

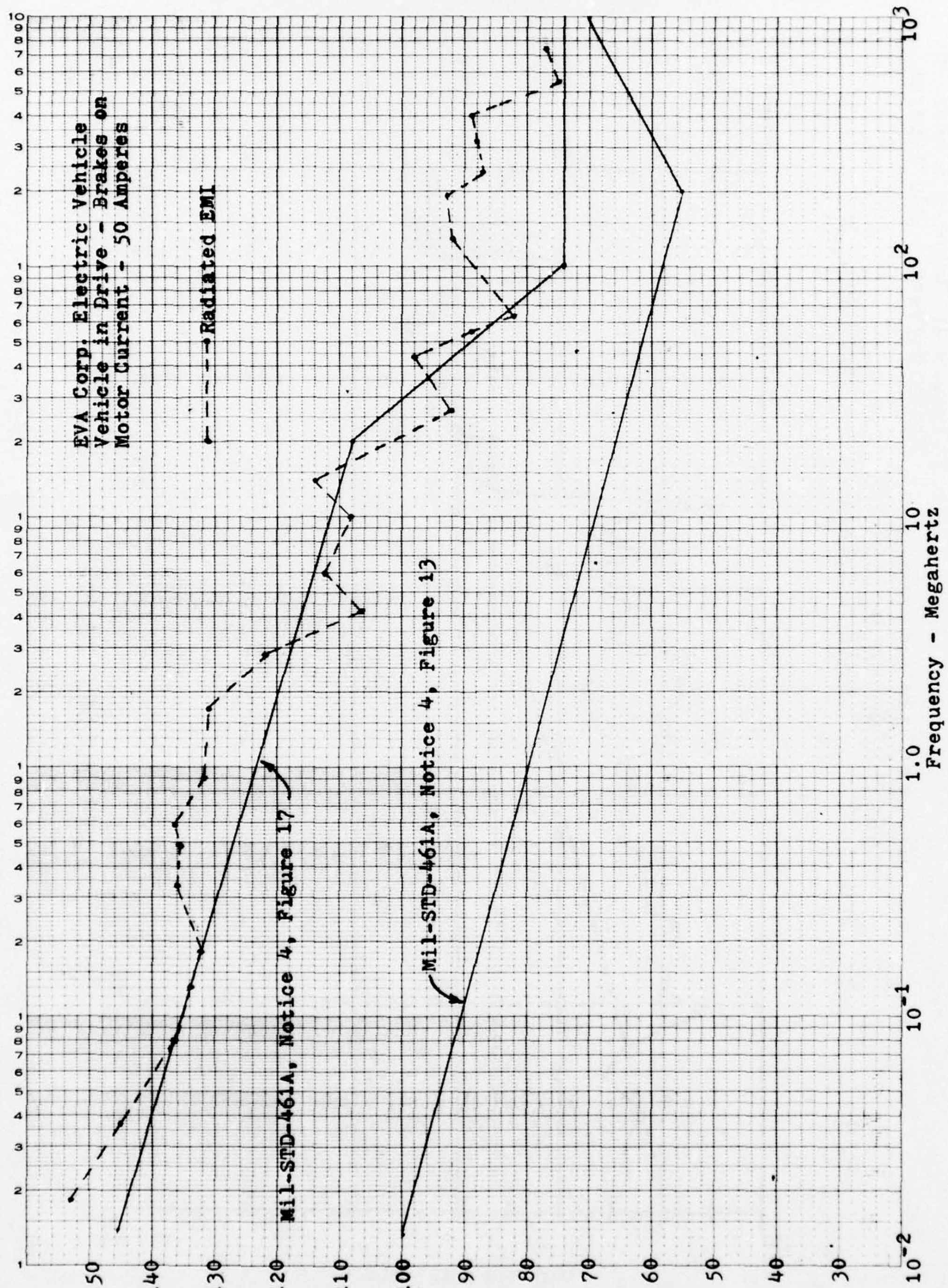


Figure 16.2. EMI test, 50A load.

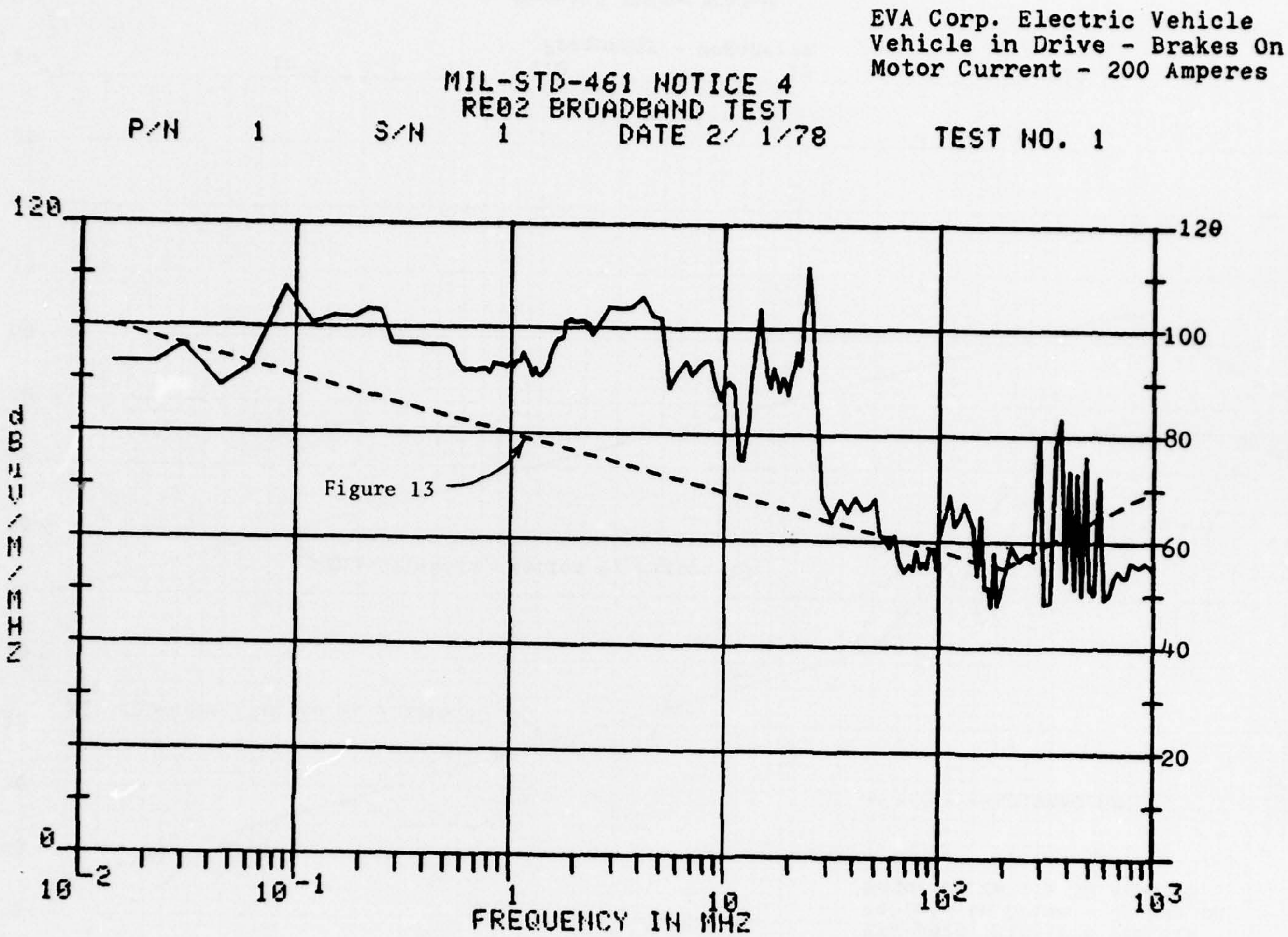


Figure 16.3. EMI test, 200A load.

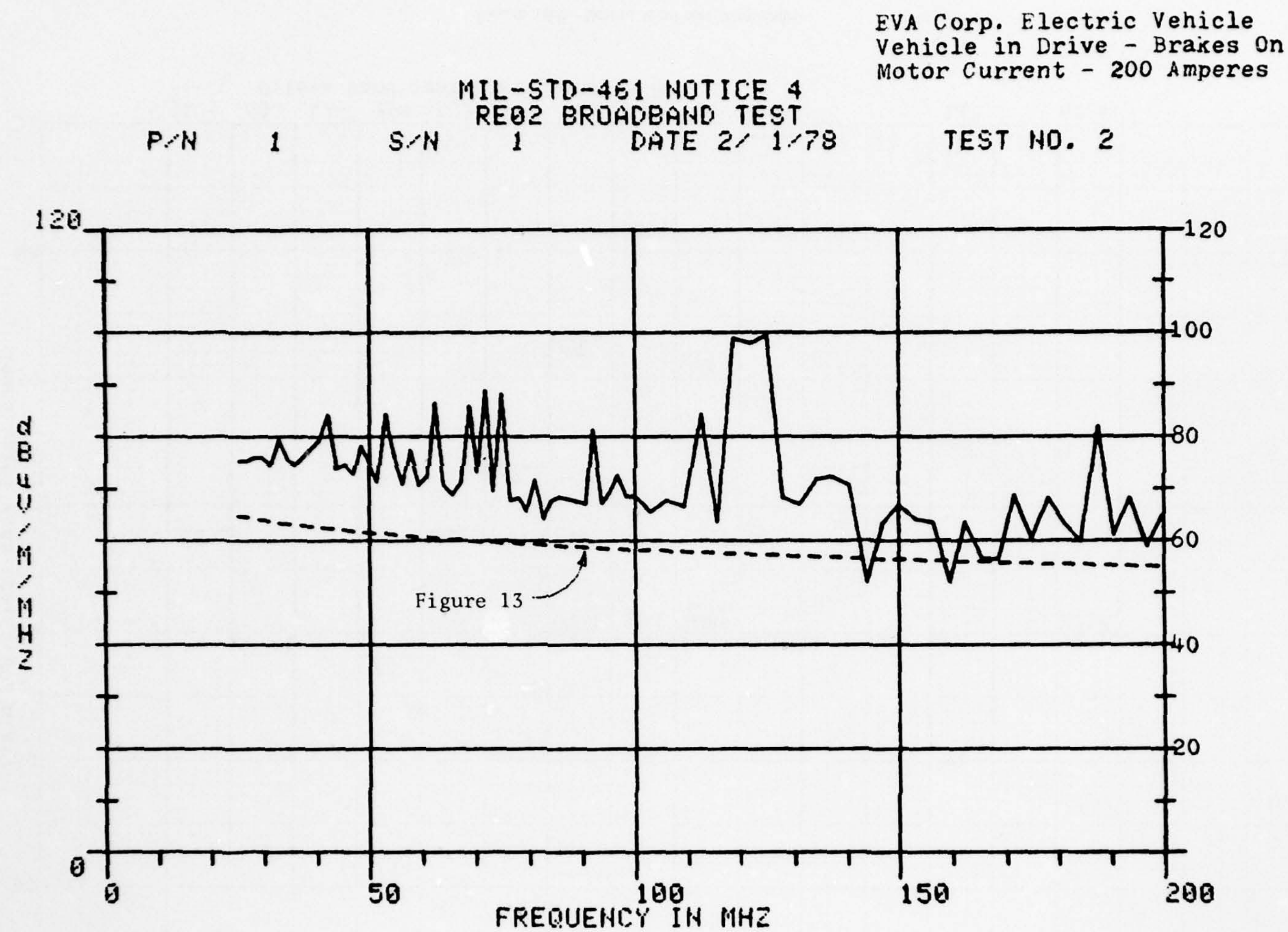


Figure 16.4. EMI test, 200A load.

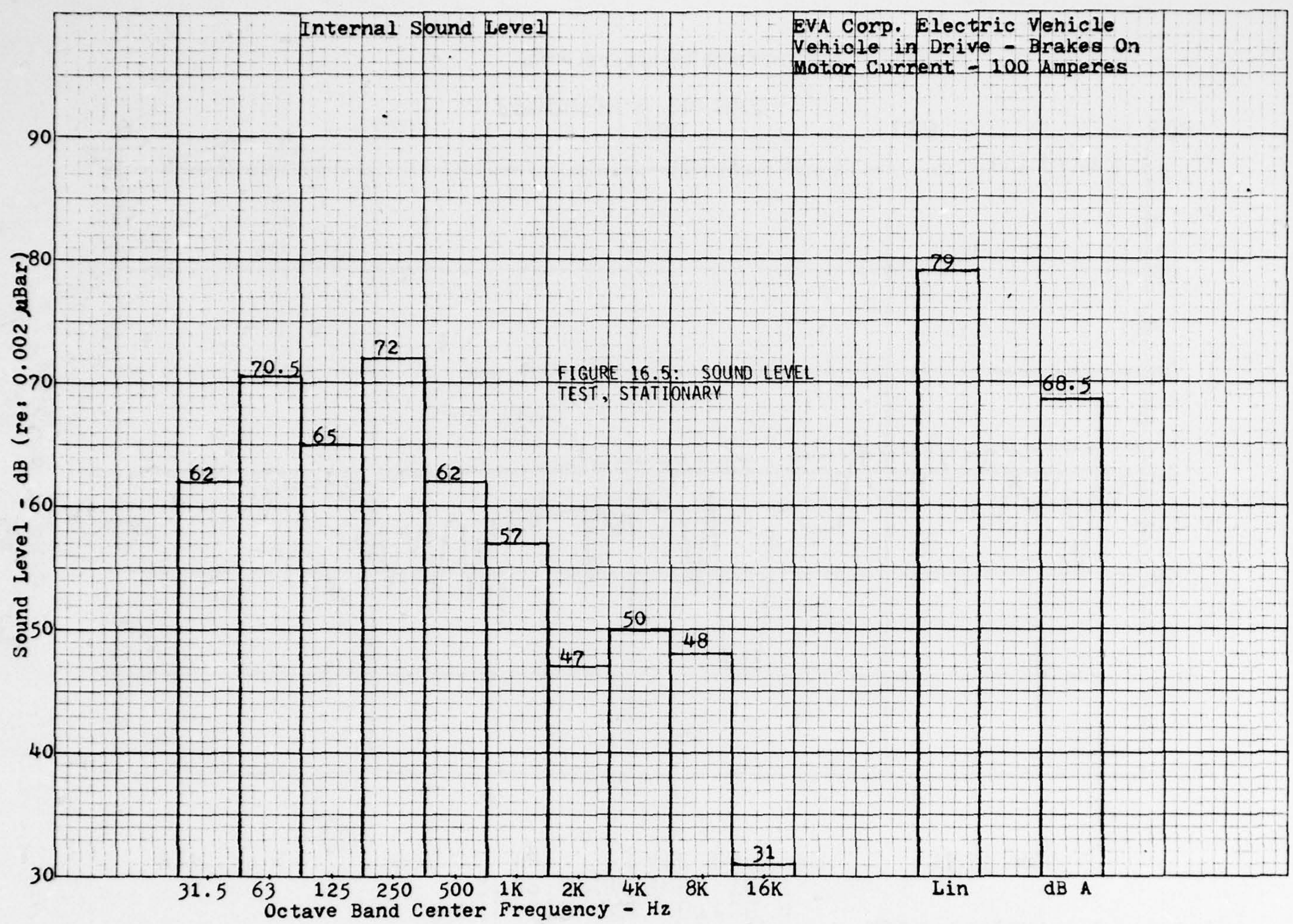


Figure 16.5. Sound level test, stationary.

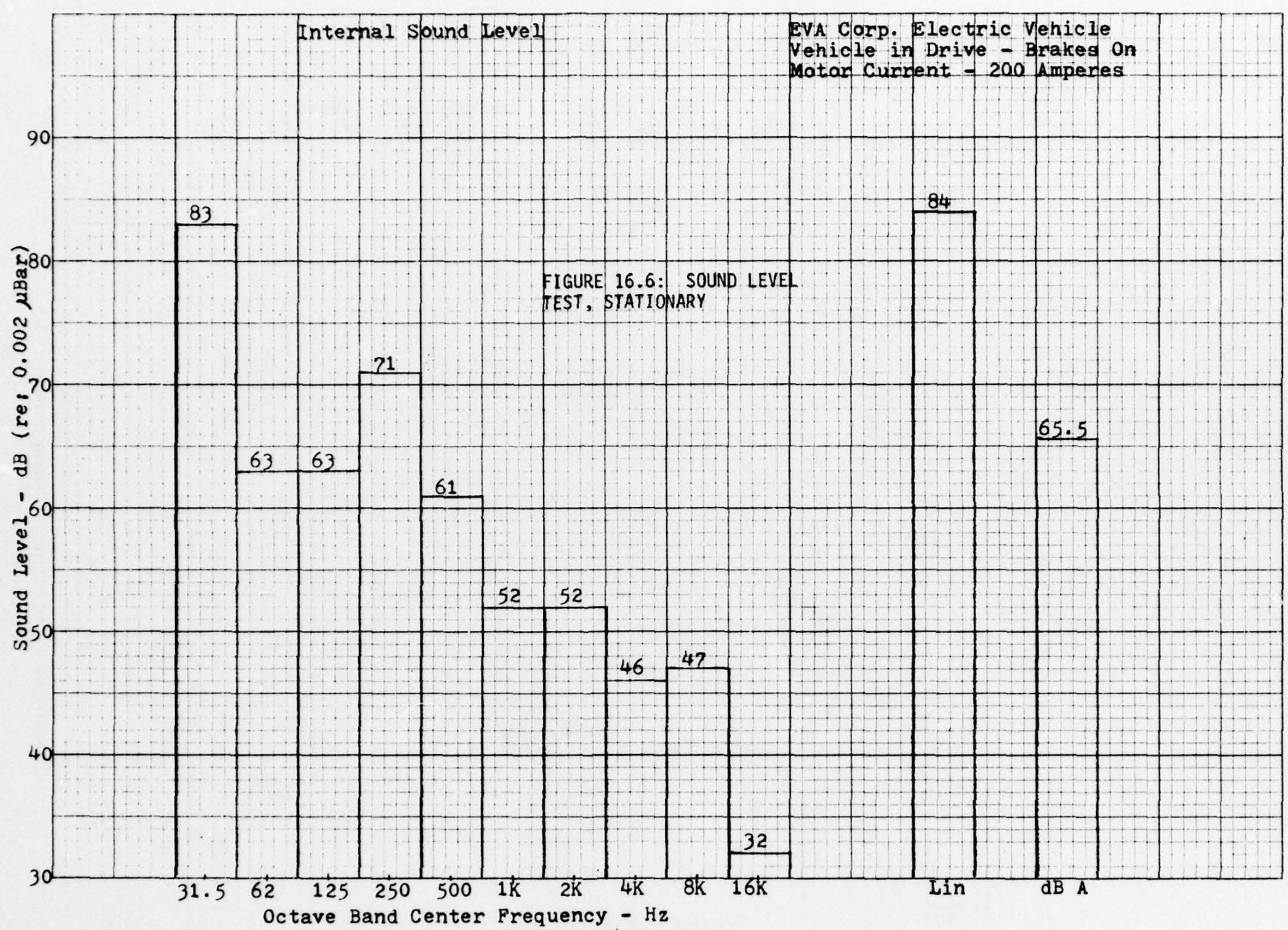


Figure 16.6. Sound level test, stationary.

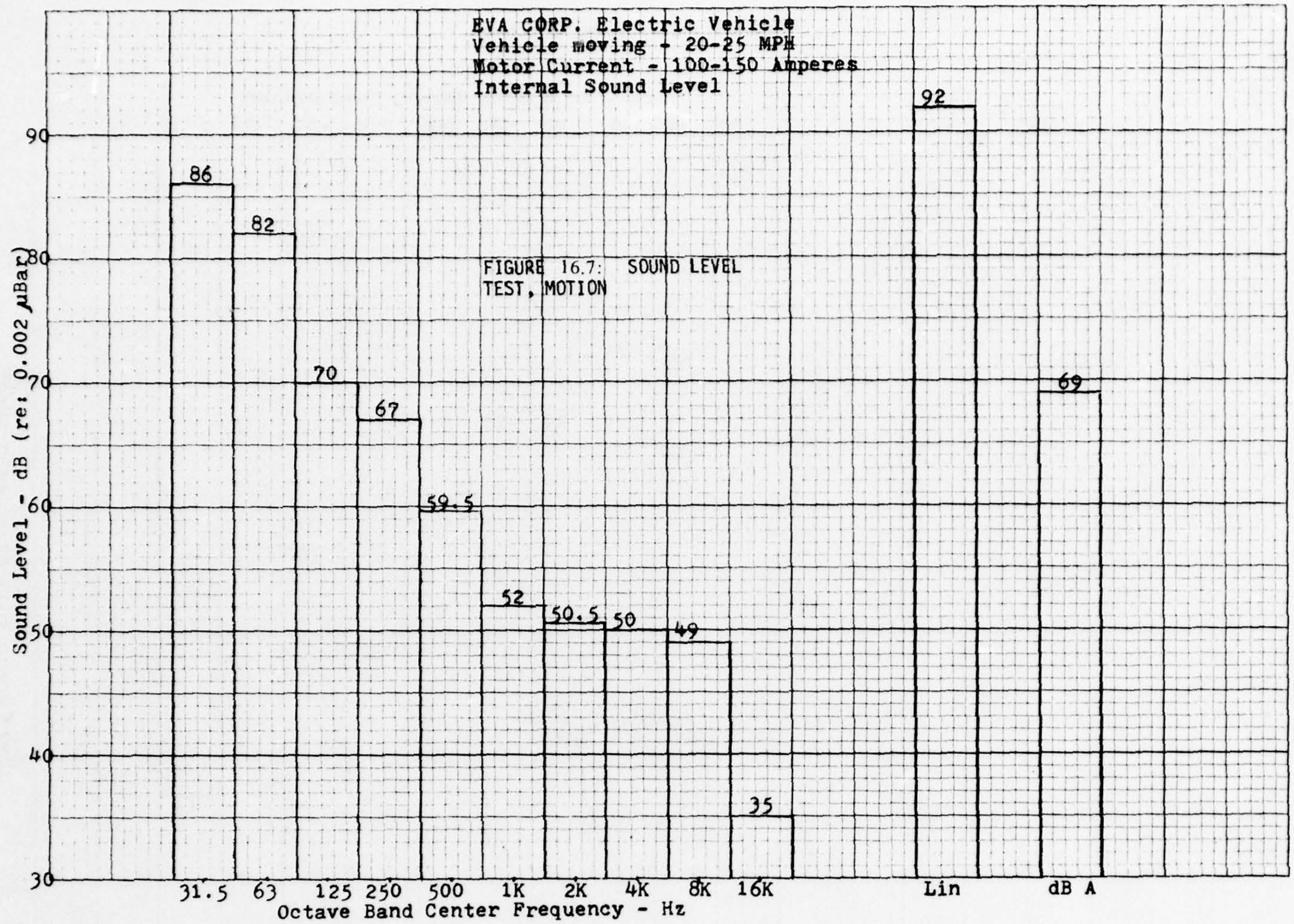


Figure 16.7. Sound level test, motion.

Table 12. Sound Levels for EVA No. 1 Metro Sedan.

OCTAVE BAND	SOUND LEVEL	BATTERY CURRENT IBAT (AVG)	
CENTER FREQUENCY	VEHICLE MOVING	100 ADC	200 ADC
Hz	DB	DB	DB
31.5	86	62	83
63	82	70.5	63
125	70	65	63
250	67	72	71
500	59.5	62	61
1000	52	57	52
2000	50.5	47	52
4000	50	50	46
8000	49	48	47
16000	35	31	32
LINEAR	92	79	84
DBA	69	68.5	65.5

source providing continuous dc power. Thus, it appears that measurements concerned with degradation of motor performance as well as battery utilization, can be attained directly with a single test run in conjunction with the dc chopper. This, of course, simplifies the performance evaluation of such a propulsion drive.

The measurement of energy transfer efficiency in a battery has been reduced to a simple test. The battery is charged at any arbitrarily set value as long as constant gas pressure and flow rate is maintained. Under these conditions, energy transfer efficiency can be measured for various rates of discharge, and for constant ampere-hour charge and discharge ratios. The attained efficiencies described in the report can be improved by replacing the pulsating charge current with a continuous dc current. In this way the peak amplitude would be reduced while the identical average charge current would be maintained.

XVIII. REFERENCES

Reference	Description
1	"A Low Cost Thyristor Fuse," by Eberhart Reimers, IEEE Transactions on Industry Application, Vol. IA – 12, No. 2, March/April 1976, pp. 172-179.
2	"Design Analysis of Multiphase DC Chopper Motor Drive," by Eberhart Reimers, IEEE Transactions on Industry Application, Vol. IA – 8, No. 2, March/April 1972, pp. 136-144.
3	"Wide Temperature Range Charging System Controlled by Battery Acceptance," by Joseph A. Mas, Transactions of the New York Academy of Sciences, Div. of Engineering, 1967, pp. 615-626, Presented on October 11, 1967.
4	"3052A Automatic Data Acquisition System Library," Vol. IIIA pp. 1-2 and 1-3, Hewlett-Packard Company, 1976, Loveland, CO 80537.
5	"Charge and Discharge Data, Minimal Gas Evolution on Charge, Watt-Hour Determination of End-of-Charge," by E. E. Moyer, E^2 M Engineering Services, MERADCOM Contract DAAK-78-M-2379.
6	"3052A Automatic Data Acquisition System Library," Vol 1A, Section III, p. 31.
7	"Base Line Tests of the EVA Metro Electric Passenger Vehicle," by E. J. Dowgiallo, et al., MERADCOM Report 2244, May 78.

APPENDIX A

APPLICATION OF SAMPLING TECHNIQUE

The sampling delay (D) is calculated by using equation (A.1):

(A.1) $$D = (T/X) \cdot (1 - 1/N)$$

whereby

D = Delay Time
T = Average period observed with the frequency counter
N = Total number of samples within one measurement
X = Number of samples per cycle of test waveform

The result of a 100-point sampling test with X = 2 is shown in Table A2. The decimal portion of the T(-) numbers represents the fractional position along the waveform that is sampled from an arbitrary starting point while the integer (+)1 represents the relative position in the waveform.

A graphic example of this is given in Figure 8.4 where successive waveforms are assumed to be overlaid; consecutive samples are labelled 1, 2, 3, 4, etc. For convenience t = 0 is set at the initiation of the sinewave, though it can occur anywhere in the cycle in reality. The period averaging function is performed by an HP 5302A Universal Counter Module. This counter uses from 9 to 90 milliseconds to perform the period averaging function; the number of periods averaged is 1, 10, 100, or 1000, depending upon frequency. The period average function is performed by counting the instrument's 10 megahertz oscillator for one of the indicated number of periods until a total count between 90000 and 900000 (9 to 90 ms) is obtained. This somewhat parallels the modification of the delay equation (change in X) so that at lower frequencies a lower number of cycles is required to get complete waveform sampling. The rate selection will be accomplished by software comparison of the period average input value and appropriate stepping criteria. The example shown was dictated by the high speed DVM's maximum sample rate of less than 5700 samples per second; for the 2 kilohertz signal frequency the sampling rate (X = 2) is greater than 4000 per second and required 50 cycles (25 milliseconds) for a 100 sample test. At 60 Hertz this technique would require 8333 milliseconds to accumulate the data. Thus, it is obviously advantageous to compress the sampling time by altering the delay time as allowed by the frequency of the waveform being sampled. Sampling map points for X = 3, 4 and 10 are given in Tables 3, 4, and 5 respectively.

The results of using this technique on a variety of 2 kilohertz waveforms (X = 2) are given in Table A6. For these tests the voltage was approximately 10 volts peak-to-peak with successive data groupings corresponding to zero, positive, and negative offset, respectiviely. The offsets shift the waveform to near zero-based values, but not exactly to zero. The output data are:

N = Total number of data points in sample.
A+= Average of all positive values over N samples.
A- = Average of all negative values over N samples.
N+= Number of positive readings.
N- = Number of negative readings.
Nϕ= Number of null (zero) readings.

The samples originate at random phase from a free running input. The anticipated positive and negative averages for the symmetric sinewave and squarewave are approximately 1.59 and 2.5 volts, respectively, while the offset waveforms would have magnitudes near 5.0 and 0.0 for the positive and negative averages for positive offset and near 0.0 and -5.0 for negative offsets. These expectations match the data to within the accuracy of the amplitude setting and the function generator characteristics. The important point to note is the number of positive and negative samples in each case. The square wave data clearly show a worst case 51.49 polarity ratio for the sampling, while the sine wave data shows a 40:50 split when symmetric and 98:2 split when offset. These results indicate that sampling is quite well spaced along the waveform. This is further corroborated by the positive and negative pulse data. In these cases the pulse width is approximately 15% of the total period, so that the expected magnitudes would be about .75 and 4.75 volts on the unshifted waveforms and 1.5 and 8.5 volts in the case of shifted waveforms; the magnitude results match reasonably and the N+ and N- numbers show good agreement with the expected values. It can be concluded that a valid technique for determining "V_{AVG}" has been improved by increasing the number of samples, if necessary. In this way a typically 2000 Hertz pulse duration waveform (PDM) can be analyzed with a sampling rate just over 4000 Hertz.

S	T	S	T
1	0.495	2	0.990
3	1.485	4	1.980
5	2.475	6	2.970
7	3.465	8	3.960
9	4.455	10	4.950
11	5.445	12	5.940
13	6.435	14	6.930
15	7.425	16	7.920
17	8.415	18	8.910
19	9.405	20	9.900
21	10.395	22	10.890
23	11.385	24	11.880
25	12.375	26	12.870
27	13.365	28	13.860
29	14.355	30	14.850
31	15.345	32	15.840
33	16.335	34	16.830
35	17.325	36	17.820
37	18.315	38	18.810
39	19.305	40	19.800
41	20.295	42	20.790
43	21.285	44	21.780
45	22.275	46	22.770
47	23.265	48	23.760
49	24.255	50	24.750
51	25.245	52	25.740
53	26.235	54	26.730
55	27.225	56	27.720
57	28.215	58	28.710
59	29.205	60	29.700
61	30.195	62	30.690
63	31.185	64	31.680
65	32.175	66	32.670
67	33.165	68	33.660
69	34.155	70	34.650
71	35.145	72	35.640
73	36.135	74	36.630
75	37.125	76	37.620
77	38.115	78	38.610
79	39.105	80	39.600
81	40.095	82	40.590
83	41.085	84	41.580
85	42.075	86	42.570
87	43.065	88	43.560
89	44.055	90	44.550
91	45.045	92	45.540
93	46.035	94	46.530
95	47.025	96	47.520
97	48.015	98	48.510
99	49.005	100	49.500

TABLE A1: Relative Sample Points for $D = (T/2)(1-1/N)$, $N=100$.

S	T	S	T
1	0.3300	2	0.6600
3	0.9900	4	1.3200
5	1.6500	6	1.9800
7	2.3100	8	2.6400
9	2.9700	10	3.3000
11	3.6300	12	3.9600
13	4.2900	14	4.6200
15	4.9500	16	5.2800
17	5.6100	18	5.9400
19	6.2700	20	6.6000
21	6.9300	22	7.2600
23	7.5900	24	7.9200
25	8.2500	26	8.5800
27	8.9100	28	9.2400
29	9.5700	30	9.9000
31	10.2300	32	10.5600
33	10.8900	34	11.2200
35	11.5500	36	11.8800
37	12.2100	38	12.5400
39	12.8700	40	13.2000
41	13.5300	42	13.8600
43	14.1900	44	14.5200
45	14.8500	46	15.1800
47	15.5100	48	15.8400
49	16.1700	50	16.5000
51	16.8300	52	17.1600
53	17.4900	54	17.8200
55	18.1500	56	18.4800
57	18.8100	58	19.1400
59	19.4700	60	19.8000
61	20.1300	62	20.4600
63	20.7900	64	21.1200
65	21.4500	66	21.7800
67	22.1100	68	22.4400
69	22.7700	70	23.1000
71	23.4300	72	23.7600
73	24.0900	74	24.4200
75	24.7500	76	25.0800
77	25.4100	78	25.7400
79	26.0700	80	26.4000
81	26.7300	82	27.0600
83	27.3900	84	27.7200
85	28.0500	86	28.3800
87	28.7100	88	29.0400
89	29.3700	90	29.7000
91	30.0300	92	30.3600
93	30.6900	94	31.0200
95	31.3500	96	31.6800
97	32.0100	98	32.3400
99	32.6700	100	33.0000

TABLE A2: Relative Sample Points for $D = (T/3)(1-1/N)$, N=100.

S	T	S	T
1	0.2475	2	0.4950
3	0.7425	4	0.9900
5	1.2375	6	1.4850
7	1.7325	8	1.9800
9	2.2275	10	2.4750
11	2.7225	12	2.9700
13	3.2175	14	3.4650
15	3.7125	16	3.9600
17	4.2075	18	4.4550
19	4.7025	20	4.9500
21	5.1975	22	5.4450
23	5.6925	24	5.9400
25	6.1875	26	6.4350
27	6.6825	28	6.9300
29	7.1775	30	7.4250
31	7.6725	32	7.9200
33	8.1675	34	8.4150
35	8.6625	36	8.9100
37	9.1575	38	9.4050
39	9.6525	40	9.9000
41	10.1475	42	10.3950
43	10.6425	44	10.8900
45	11.1375	46	11.3850
47	11.6325	48	11.8800
49	12.1275	50	12.3750
51	12.6225	52	12.8700
53	13.1175	54	13.3650
55	13.6125	56	13.8600
57	14.1075	58	14.3550
59	14.6025	60	14.8500
61	15.0975	62	15.3450
63	15.5925	64	15.8400
65	16.0875	66	16.3350
67	16.5825	68	16.8300
69	17.0775	70	17.3250
71	17.5725	72	17.8200
73	18.0675	74	18.3150
75	18.5625	76	18.8100
77	19.0575	78	19.3050
79	19.5525	80	19.8000
81	20.0475	82	20.2950
83	20.5425	84	20.7900
85	21.0375	86	21.2850
87	21.5325	88	21.7800
89	22.0275	90	22.2750
91	22.5225	92	22.7700
93	23.0175	94	23.2650
95	23.5125	96	23.7600
97	24.0075	98	24.2550
99	24.5025	100	24.7500

TABLE A3: Relative Sample Points for $D = (T/4)(1-1/N)$, $N=100$.

S	T	S	T
1	0.0990	2	0.1980
3	0.2970	4	0.3960
5	0.4950	6	0.5940
7	0.6930	8	0.7920
9	0.8910	10	0.9900
11	1.0890	12	1.1880
13	1.2870	14	1.3860
15	1.4850	16	1.5840
17	1.6830	18	1.7820
19	1.8810	20	1.9800
21	2.0790	22	2.1780
23	2.2770	24	2.3760
25	2.4750	26	2.5740
27	2.6730	28	2.7720
29	2.8710	30	2.9700
31	3.0690	32	3.1680
33	3.2670	34	3.3660
35	3.4650	36	3.5640
37	3.6630	38	3.7620
39	3.8610	40	3.9600
41	4.0590	42	4.1580
43	4.2570	44	4.3560
45	4.4550	46	4.5540
47	4.6530	48	4.7520
49	4.8510	50	4.9500
51	5.0490	52	5.1480
53	5.2470	54	5.3460
55	5.4450	56	5.5440
57	5.6430	58	5.7420
59	5.8410	60	5.9400
61	6.0390	62	6.1380
63	6.2370	64	6.3360
65	6.4350	66	6.5340
67	6.6330	68	6.7320
69	6.8310	70	6.9300
71	7.0290	72	7.1280
73	7.2270	74	7.3260
75	7.4250	76	7.5240
77	7.6230	78	7.7220
79	7.8210	80	7.9200
81	8.0190	82	8.1180
83	8.2170	84	8.3160
85	8.4150	86	8.5140
87	8.6130	88	8.7120
89	8.8110	90	8.9100
91	9.0090	92	9.1080
93	9.2070	94	9.3060
95	9.4050	96	9.5040
97	9.6030	98	9.7020
99	9.8010	100	9.9000

TABLE A4: Relative Sample Points for $D = (T/10)(1-1/N)$, $N=100$.

SQUARE WAVE		SINE WAVE		POSITIVE PULSE		NEGATIVE PULSE	
N=	100.00	N=	100.00	N=	100.00	N=	100.00
A+=	2.67	A+=	1.57	A+=	0.78	A+=	4.34
A-=	-2.48	A-=	-1.62	A-=	-4.31	A-=	-0.86
N+=	51.00	N+=	50.00	N+=	15.00	N+=	83.00
N-=	49.00	N-=	50.00	N-=	85.00	N-=	17.00
N0=	0.00	N0=	0.00	N0=	0.00	N0=	0.00
N=	100.00	N=	100.00	N=	100.00	N=	100.00
A+=	5.10	A+=	4.95	A+=	1.53	A+=	8.77
A-=	-0.05	A-=	-0.00	A-=	-0.09	A-=	-0.01
N+=	50.00	N+=	98.00	N+=	15.00	N+=	86.00
N-=	50.00	N-=	2.00	N-=	85.00	N-=	14.00
N0=	0.00	N0=	.0.00	N0=	0.00	N0=	0.00
N=	100.00	N=	100.00	N=	100.00	N=	100.00
A+=	0.13	A+=	0.00	A+=	0.04	A+=	0.22
A-=	-5.12	A-=	-4.97	A-=	-8.63	A-=	-1.51
N+=	49.00	N+=	1.00	N+=	14.00	N+=	85.00
N-=	51.00	N-=	98.00	N-=	86.00	N-=	15.00
N0=	0.00	N0=	1.00	N0=	0.00	N0=	0.00

TABLE A5: Results of Period Synchronized Sampling of Various 2 kHz. Waveforms.

APPENDIX B

EVA TRANSMISSION TEST ROUTINE

SOFTWARE AND DATA PRINT-OUT

```
0: dsp "EVA TRANSMISSION TEST ROUTINE"
1: dsp "PROGRAM TAPE TRACK 0, FILE 23"
2: dsp "PROGRAM UPDATE: 3-19-79"
3: clr 7
4: dim A[18,10];dim B[18,10];dim C$[13]
5: dsp "PUT DATA TAPE IN CALCULATOR";stp
6: enp "DATA TAPE TRACK: ",D;trk D
7: enp "FIRST RAW DATA  FILE = ",G;gto "data"
8: "avg 1":
9: wrt 722,"B;U=>";wait 100;trg 722
10: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
11: I+1→I;ret
12: "avg 10":
13: wrt 722,"B;U;>";wait 100;trg 722
14: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
15: I+1→I;ret
16: "avg 100":
17: wrt 722,"B;U7>";wait 100;trg 722
18: red 722.2,A[I,P];clr 722
19: I+1→I;ret
20: "rms 1":
21: wrt 722,"B;U==";wait 100;trg 722
22: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
23: I+1→I;ret
24: "rms 10":
25: wrt 722,"B;U;=";wait 100;trg 722
26: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
27: I+1→I;ret
28: "rms 100":
29: wrt 722,"B;U7=";wait 100;trg 722
30: red 722.2,A[I,P];clr 722
31: I+1→I;ret
32: dsp "CLOCK READ AND PRINT, NO CR/LF"
33: "clockread":
34: fmt 8,c1;wrt 708.8,"C";fmt 8,c12;red 708.8,C$;clr 708;ret
35: "clockprint":
36: fmt 1,c2,z;fmt 2,"-",z;fmt 3,":",z
37: fmt 4,5x,z;fmt 5,3/;fmt 6,"79-",z;wrt 715.5
38: wrt 715.6;wrt 715.1,C$[3,4];wrt 715.2;wrt 715.1,C$[5,6]
39: wrt 715.4;wrt 715.1,C$[7,8];wrt 715.3;wrt 715.1,C$[9,10]
40: wrt 715.3;wrt 715.1,C$[11,12];wrt 715.4;ret
41: "poly":
42: if p0<11;gto +2
43: (((((((p1p18+p17)p1+p16)p1+p15)p1+p14)p1+p13)p1+p12)p1+p11)p1→p20
44: ((((((((p20+p10)p1+p9)p1+p8)p1+p7)p1+p6)p1+p5)p1+p4)p1+p3)p1→p20
45: ret p20+p2
46: "*temp T":
47: if p2>0;gto +8
48: 0→p3;3.874077384e1→p4;4.4123932482e-2→p5;1.1405238498e-4→p6
49: 1.9974406568e-5→p7;9.0445401187e-7→p8;2.2766018504e-8→p9
50: 3.624740938e-10→p10;3.8648924201e-12→p11;2.8298678519e-14→p12
```

```
51: 1.4281383349e-16→p13;4.8833254364e-19→p14;1.0803474683e-21→p15
52: 1.3949291026e-24→p16;7.9795893156e-28→p17;if p24>0;gto +10
53: 'poly'(p2,p3,p4,p5,p6,p7,p8,p9,p10,p11,p12,p13,p14,p15,p16,p17)→p20
54: p20/1e6+p1→p20;gto +5
55: 0→p3;3.874077384e1→p4;3.3190198092e-2→p5;2.0714183645e-4→p6
56: -2.1945834823e-6→p7;1.103190055e-8→p8;-3.0927581898e-11→p9
57: 4.5653337165e-14→p10;-2.761687804e-17→p11;if p24>0;gto +11
58: 'poly'(p2,p3,p4,p5,p6,p7,p8,p9,p10,p11)/1e6+p1→p20
59: .002→p21
60: 1→p24;if p20>0;gto -5
61: gto -13
62: 'poly'(p21,p3,p4,p5,p6,p7,p8,p9,p10,p11,p12,p13,p14,p15,p16,p17)/1e6→p22
63: p22-p20→p22
64: if abs(p22)<.0000001;ret p21
65: 'poly'(p21,0,0,0,0,0,0,7p10,8p11,9p12,10p13,11p14,12p15,13p16,14p17)→p23
66: (p23+'poly'(p21,p4,2p5,3p6,4p7,5p8,6p9))/1e6→p23
67: p21-p22/p23→p21;gto -5
68: 'poly'(p21,p3,p4,p5,p6,p7,p8,p9,p10,p11)/1e6-p20→p22
69: if abs(p22)<.0000001;ret p21
70: 'poly'(p21,p4,2p5,3p6,4p7,5p8,6p9,7p10,8p11)/1e6→p23
71: p21-p22/p23→p21;gto -3
72: "data":
73: dsp "PRESS CONTINUE TO CLEAR ARRAYS";stp
74: for I=1 to 18
75: for J=1 to 10
76: 0→A[I,J]
77: next J
78: next I
79: for I=1 to 18
80: for J=1 to 10
81: 0→B[I,J]
82: next J
83: next I
84: 0→H
85: dsp "PRESS CONTINUE TO READ DATA";stp
86: for P=1 to 10
87: H+1→H;1→I
88: fmt 1,3x,e14.4;fmt 2,e13.6,z;fmt 5,f3.0
89: wrt 709.5,"C",0
90: gsb "avg 10"
91: wrt 709.5,"C",1
92: gsb "avg 10"
93: wrt 709.5,"C",2
94: gsb "avg 1"
95: wrt 709.5,"C",3
96: gsb "avg 10"
97: wrt 709.5,"C",4
98: gsb "avg 10"
99: for Q=10 to 12
100: wrt 709.5,"C",Q
101: gsb "avg 100"
102: next Q
103: wrt 709.5,"C",20
104: gsb "avg 1"
```

```
105: wrt 709.5,"C",34;wait 100
106: wrt 714,"I"
107: time 2000
108: on err "T1"
109: red 714.1,A[I,P];jmp 2
110: "T1":0→A[I,P];dsp "NO TRANSMISSION INPUT SPEED";jmp 2
111: dsp "TRANSMISSION INPUT SPEED MEASURED"
112: clr 709;I+1→I
113: wrt 709.5,"C",35;wait 100
114: wrt 714,"I"
115: time 2000
116: on err "T2"
117: red 714.1,A[I,P];jmp 2
118: "T2":0→A[I,P];dsp "NO TRANSMISSION OUTPUT SPEED";jmp 2
119: dsp "TRANSMISSION OUTPUT SPEED MEASURED"
120: clr 709;I+1→I
121: wrt 709.5,"C",5
122: gsb "avg 1"
123: wrt 709.5,"C",6
124: gsb "avg 1"
125: for Q=10 to 12
126: wrt 709.5,"C",Q
127: gsb "rms 100"
128: next Q
129: wrt 709.5,"C",20
130: gsb "rms 1"
131: dsp "MEASUREMENTS COMPLETE";wait 1000;clr 7
132: dsp "NEW TORQUE SETTING?";wait 2500
133: dsp "PRESS CONTINUE WHEN READY";stp
134: next P
135: "record A":
136: dsp "PRESS CONTINUE TO RECORD A-ARRAY";stp
137: rcf G,A[*]
138: G+1→G;1→I
139: "convert":
140: dsp "CONVERT TO TRUE DATA"
141: on err "E2";jmp 2
142: "E2":dsp "ERROR IN CONVERT ROUTINE";stp
143: for P=1 to H
144: 2*A[10,P]→B[1,P]
145: 2*A[11,P]→B[2,P]
146: -1*13316*A[3,P]-15.09→B[3,P]
147: 50*A[1,P]*1.3558→B[4,P]
148: 8.333*A[2,P]*1.3558→B[5,P]
149: if A[4,P]>5;if A[5,P]>5;1→B[6,P]
150: if A[4,P]<5;if A[5,P]>5;2→B[6,P]
151: if A[4,P]<5;if A[5,P]<5;3→B[6,P]
152: if B[6,P]=1;8.3→B[7,P]
153: if B[6,P]=2;5.13→B[7,P]
154: if B[6,P]=3;3.56→B[7,P]
155: 100*(B[1,P]-B[7,P]*B[2,P])/B[1,P]→B[8,P]
156: B[1,P]*B[8,P]/100/60→B[9,P]
157: B[2,P]*B[4,P]/5252/1.3558→B[10,P]
158: 745.7*B[10,P]→B[11,P]
```

```
159: B[1,P]*B[5,P]/5252/1.3558→B[12,P]
160: 745.7*B[12,P]→B[13,P]
161: 100*B[10,P]/B[12,P]→B[14,P]
162: (B[13,P]-B[11,P])/B[4,P]→B[15,P]
163: '*temp T'(A[12,P])→B[16,P]
164: '*temp T'(A[13,P])→B[17,P]
165: next P
166: "record B":
167: dsp "PRESS CONTINUE TO RECORD B-ARRAY";stp
168: rcf G,B[*]
169: G+1→G
170: dsp "IS PAPER POSITIONED PROPERLY?";stp
171: "print":
172: wrt 715,"EVA TRANSMISSION TEST WITH DC POWER SOURCE"
173: wrt 715,"DC SERIES MOTOR, 10 HP, 3800 RPM"
174: wrt 715,"BALDOR ELECTRIC CO., ST. LOUIS, MO"
175: wrt 715,"SPEC: 29 1755 1121; S.N.: 1276"
176: gsb "clockprint"
177: wrt 715,"MERADCOM, DRDME-EA, FT. BELVOIR, VA  22060";wrt 715.5
178: dsp "HEADER AND DATE/TIME PRINTED"
179: fmt 4,f2.0,z;fmt 6,x,f9.3,z;fmt 9,2x,c11,z
180: 18→M
181: for I=1 to M-1
182: wrt 715.4,I
183: jmp I
184: wrt 715.9,"NTR      RPM";jmp M-I
185: wrt 715.9,"NO       RPM";jmp M-I
186: wrt 715.9,"TQ      FT-#";jmp M-I
187: wrt 715.9,"TO        Nm";jmp M-I
188: wrt 715.9,"TMOT      Nm";jmp M-I
189: wrt 715.9,"GEAR SELECT";jmp M-I
190: wrt 715.9,"GR  RATIO:1";jmp M-I
191: wrt 715.9,"NSL        %";jmp M-I
192: wrt 715.9,"SL       RPS";jmp M-I
193: wrt 715.9,"PO        HP";jmp M-I
194: wrt 715.9,"PO         W";jmp M-I
195: wrt 715.9,"PTR       HP";jmp M-I
196: wrt 715.9,"PTR        W";jmp M-I
197: wrt 715.9,"TRANS EFF %";jmp M-I
198: wrt 715.9,"WLTR   W/Nm";jmp M-I
199: wrt 715.9,"TRAN TEMP C";jmp M-I
200: wrt 715.9,"MOTR TEMP C";jmp M-I
201: for P=1 to H
202: wrt 715.6,abs(B[I,P])
203: next P
204: wrt 715," "
205: next I
206: wtb 715,12
207: "raw data":
208: dsp "PRINT RAW DATA?";stp
209: wrt 715,"EVA TRANSMISSION TEST RAW DATA"
210: fmt 3,c14,f3.0;wrt 715.3,"DATA ON FILE: ",G-2
211: gsb "clockprint"
212: wrt 715.5;fmt 4,f2.0,z;fmt 6,x,f9.4,z
```

```
213: 18→M
214: for I=1 to M-1
215: wrt 715.4,I
216: jmp I
217: wrt 715.9,"TO       VDC";jmp M-I
218: wrt 715.9,"TMOT     VDC";jmp M-I
219: wrt 715.9,"TQ       VDC";jmp M-I
220: wrt 715.9,"SOL 1    VDC";jmp M-I
221: wrt 715.9,"SOL 2    VDC";jmp M-I
222: wrt 715.9,"EBAT     VDC";jmp M-I
223: wrt 715.9,"EARM     VDC";jmp M-I
224: wrt 715.9,"EFM      VDC";jmp M-I
225: wrt 715.9,"IARM     VDC";jmp M-I
226: wrt 715.9,"NTR       HZ";jmp M-I
227: wrt 715.9,"NQ        HZ";jmp M-I
228: wrt 715.9,"TEMP TR VDC";jmp M-I
229: wrt 715.9,"TEMP MT VDC";jmp M-I
230: wrt 715.9,"EBAT     RMS";jmp M-I
231: wrt 715.9,"EARM     RMS";jmp M-I
232: wrt 715.9,"EFM      RMS";jmp M-I
233: wrt 715.9,"IARM     RMS";jmp M-I
234: for P=1 to H
235: wrt 715.6,A[I,P]
236: next P
237: wrt 715," "
238: next I
239: wtb 715,12
240: gto "data"
241: end
*26537
```

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-05-23 11:21:30 MERADCOM, DRDME-EA, FT. BELVOIR, VA 2206.0

1	NTR	RPM	MOTOR ROTOR SPEED, TRANSMISSION INPUT
2	NO	RPM	WHEEL (DYNAMOMETER) SPEED, TRANSMISSION OUTPUT
3	TQ	FT-#	TRANSMISSION TORQUE READ-OUT
4	TO	Nm	TRANSMISSION TORQUE READ-OUT
5	TMOT	Nm	MOTOR SHAFT TORQUE
6	GEAR SELECT		TRANSMISSION GEAR SELECTION
7	GR	RATIO:1	GEAR RATIO
8	NSL	%	SLIP
9	SL	RPS	SLIP FREQUENCY
10	PO	HP	POWER OUTPUT OF TRANSMISSION
11	PO	W	POWER OUTPUT OF TRANSMISSION
12	PTR	HP	MOTOR SHAFT POWER
13	PTR	W	MOTOR SHAFT POWER
14	TRANS EFF	%	TRANSMISSION EFFICIENCY
15	WLTR	W/Nm	TRANSMISSION WATT-LOSS/TORQUE DELIVERED TO WHEEL
16	TRAN TEMP	C	TRANSMISSION OIL TEMPERATURE
17	MOTR TEMP	C	MOTOR FIELD WINDING TEMPERATURE

Table B1. Transmission Test Nomenclature.

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 112D; S.N.: 1276

79-06-22 10:04:04 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1646.000	2036.000	2550.000	3200.000
2	NO	RPM	174.000	224.000	288.000	366.000
3	TQ	FT-#	178.671	180.575	172.200	170.602
4	TO	Nm	257.073	258.968	246.953	243.735
5	TMOT	Nm	37.399	38.327	37.572	38.027
6	GEAR SELECT		1.000	1.000	1.000	1.000
7	GR RATIO:1		8.300	8.300	8.300	8.300
8	NSL	%	12.260	8.684	6.259	5.069
9	SL	RPS	3.363	2.947	2.660	2.703
10	PO	HP	6.282	8.147	9.988	12.528
11	PO	W	4684.356	6074.882	7448.183	9342.058
12	PTR	HP	8.645	10.959	13.455	17.089
13	PTR	W	6446.611	8172.021	10033.527	12743.293
14	TRANS EFF	%	72.664	74.338	74.233	73.310
15	WLTR	W/Nm	6.855	8.098	10.469	13.955
16	TRAN TEMP	C	75.458	75.235	70.559	68.624
17	MOTR TEMP	C	47.114	49.855	51.838	53.418

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 1121; S.N.: 1276

79-06-22 11:01:45 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1302.000	1642.000	2048.000	2558.000	3202.000
2	NO	RPM	132.000	178.000	230.000	292.000	368.000
3	TQ	FT-#	135.634	132.638	131.972	126.273	124.621
4	TO	Nm	195.310	190.391	188.985	179.014	178.175
5	TMOT	Nm	29.935	29.736	30.073	29.768	29.744
6	GEAR	SELECT	1.000	1.000	1.000	1.000	1.000
7	GR	RATIO:1	8.300	8.300	8.300	8.300	8.300
8	NSL	%	15.853	10.024	6.787	5.254	4.610
9	SL	RPS	3.440	2.743	2.317	2.240	2.460
10	PO	HP	3.621	4.759	6.104	7.341	9.208
11	PO	W	2699.863	3549.033	4551.965	5474.124	6866.553
12	PTR•	HP	5.474	6.857	8.649	10.694	13.375
13	PTR	W	4081.662	5113.264	6449.847	7974.204	9973.941
14	TRANS EFF	%	66.146	69.408	70.575	68.648	68.845
15	WLTR	W/Nm	7.075	8.216	10.043	13.966	17.440
16	TRAN TEMP	C	73.070	72.488	71.547	67.902	65.572
17	MOTR TEMP	C	40.967	43.317	45.160	46.456	48.240

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 1121; S.N.: 1276

79-06-22 10:59:18 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1046.000	1310.000	1640.000	2044.000	2558.000	3196.000
2	NO	RPM	96.000	138.000	180.000	230.000	294.000	370.000
3	TQ	FT-#	116.485	102.570	102.344	95.246	91.158	90.120
4	TO	Nm	166.283	146.113	142.957	137.906	128.318	127.809
5	TMOT	Nm	24.585	24.094	24.286	24.041	23.921	23.866
6	GEAR SELECT		1.000	1.000	1.000	1.000	1.000	1.000
7	GR RATIO:1		8.300	8.300	8.300	8.300	8.300	8.300
8	NSL	%	23.824	12.565	8.902	6.605	4.605	3.911
9	SL	RPS	4.153	2.743	2.433	2.250	1.963	2.083
10	PO	HP	2.242	2.832	3.614	4.454	5.298	6.641
11	PO	W	1671.722	2111.603	2694.768	3321.654	3950.753	4952.283
12	PTR	HP	3.611	4.433	5.593	6.901	8.593	10.712
13	PTR	W	2693.031	3305.396	4171.040	5146.134	6407.958	7987.699
14	TRANS EFF	%	62.076	63.884	64.607	64.547	61.654	61.999
15	WLTR	W/Nm	6.142	8.170	10.327	13.230	19.149	23.750
16	TRAN TEMP	C	70.492	70.582	70.155	69.210	64.642	62.890
17	MOTR TEMP	C	39.490	40.896	41.514	42.464	43.198	44.310

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22 10:55:59 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	836.000	1048.000	1312.000	1640.000	2046.000	2556.000	3204.000
2	NO	RPM	72.000	110.000	146.000	184.000	234.000	294.000	372.000
3	TQ	FT-#	83.382	66.923	65.898	62.942	59.693	53.980	52.808
4	TO	Nm	120.575	94.497	91.441	91.312	86.382	78.159	74.870
5	TMOT	Nm	17.926	17.679	17.827	17.891	17.706	17.825	17.840
6	GEAR SELECT		1.000	1.000	1.000	1.000	1.000	1.000	1.000
7	GR	RATIO:1	8.300	8.300	8.300	8.300	8.300	8.300	8.300
8	NSL	%	28.517	12.882	7.637	6.878	5.073	4.531	3.633
9	SL	RPS	3.973	2.250	1.670	1.880	1.730	1.930	1.940
10	PO	HP	1.219	1.460	1.875	2.360	2.839	3.227	3.911
11	PO	W	909.149	1088.568	1398.102	1759.510	2116.817	2406.418	2916.718
12	PTR	HP	2.105	2.602	3.285	4.121	5.088	6.398	8.027
13	PTR	W	1569.400	1940.264	2449.415	3072.732	3793.793	4771.334	5985.934
14	TRANS EFF	%	57.930	56.104	57.079	57.262	55.797	50.435	48.726
15	WLTR	W/Nm	5.476	9.013	11.497	14.382	19.413	30.258	40.994
16	TRAN TEMP	C	68.940	68.083	67.518	66.546	64.801	61.384	58.750
17	MOTR TEMP	C	35.971	36.500	37.100	37.675	38.130	38.991	39.681

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 112J; S.N.: 1276

79-06-22 10:53:10 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	834.000	1046.000	1306.000	1636.000	2042.000	2554.000	3202.000
2	NO	RPM	88.000	116.000	146.000	186.000	236.000	296.000	374.000
3	TQ	FT-#	38.507	36.163	33.740	32.009	31.063	25.897	22.541
4	TO	Nm	58.879	53.596	52.767	50.511	46.745	40.155	35.900
5	TMOT	Nm	11.942	11.859	11.798	11.994	12.209	11.904	11.961
6	GEAR SELECT		1.000	1.000	1.000	1.000	1.000	1.000	1.000
7	GR RATIO:1		8.300	8.300	8.300	8.300	8.300	8.300	8.300
8	NSL	%	12.422	7.954	7.213	5.636	4.074	3.806	3.054
9	SL	RPS	1.727	1.387	1.570	1.537	1.387	1.620	1.630
10	PO	HP	0.728	0.873	1.082	1.319	1.549	1.669	1.886
11	PO	W	542.609	651.081	806.788	983.881	1155.297	1244.722	1406.088
12	PTR	HP	1.399	1.742	2.164	2.756	3.501	4.270	5.379
13	PTR	W	1042.984	1299.036	1613.572	2054.834	2610.824	3183.860	4010.875
14	TRANS EFF	%	52.025	50.120	50.000	47.881	44.250	39.095	35.057
15	WLTR	W/Nm	8.498	12.090	15.290	21.202	31.137	48.292	72.556
16	TRAN TEMP	C	78.700	78.212	77.591	76.281	74.655	72.130	68.196
17	MOTR TEMP	C	43.269	42.559	42.440	42.203	42.037	42.037	42.535

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22 10:50:24 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1304.000	1650.000	2044.000	2556.000	3200.000
2	NO	RPM	190.000	282.000	364.000	466.000	594.000
3	TQ	FT-#	125.713	112.730	108.323	109.255	106.379
4	TO	Nm	183.712	162.394	159.093	157.367	153.832
5	TMOT	Nm	38.009	37.439	37.261	37.612	37.757
6	GEAR SELECT		2.000	2.000	2.000	2.000	2.000
7	GR RATIO:1		5.130	5.130	5.130	5.130	5.130
8	NSL	%	25.253	12.324	8.644	6.472	4.774
9	SL	RPS	5.488	3.389	2.945	2.757	2.546
10	PO	HP	4.902	6.431	8.133	10.299	12.833
11	PO	W	3655.392	4795.830	6064.516	7679.686	9569.215
12	PTR	HP	6.961	8.675	10.696	13.501	16.968
13	PTR	W	5190.485	6469.285	7975.910	10067.810	12652.806
14	TRANS EFF	%	70.425	74.132	76.035	76.280	75.629
15	WLTR	W/Nm	8.356	10.305	12.014	15.176	20.045
16	TRAN TEMP	C	73.964	69.007	66.524	63.141	59.943
17	MOTR TEMP	C	45.985	48.569	50.276	52.349	54.137

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22   10:47:40   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1048.000	1308.000	1638.000	2050.000	2556.000	3198.000
2	NO	RPM	126.000	214.000	288.000	370.000	468.000	592.000
3	TQ	FT-#	116.445	87.204	85.432	78.868	82.583	74.114
4	TO	Nm	166.893	127.594	122.464	120.382	119.432	111.182
5	TMOT	Nm	29.908	30.287	29.747	29.951	30.257	29.503
6	GEAR SELECT		2.000	2.000	2.000	2.000	2.000	2.000
7	GR RATIO:1		5.130	5.130	5.130	5.130	5.130	5.130
8	NSL	%	38.323	16.069	9.802	7.410	6.070	5.036
9	SL	RPS	6.694	3.503	2.676	2.532	2.586	2.684
10	PO	HP	2.953	3.835	4.953	6.255	7.850	9.243
11	PO	W	2202.177	2859.493	3693.556	4664.527	5853.450	6892.850
12	PTR	HP	4.402	5.563	6.843	8.623	10.861	13.250
13	PTR	W	3282.417	4148.693	5102.629	6429.951	8099.005	9880.661
14	TRANS EFF	%	67.090	68.925	72.385	72.544	72.274	69.761
15	WLTR	W/Nm	6.473	10.104	11.506	14.665	18.802	26.873
16	TRAN TEMP	C	69.705	68.218	63.960	59.783	57.624	55.109
17	MOTR TEMP	C	40.324	42.226	43.530	45.349	46.714	48.217

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EVA METRO SEDAN ELECTRIC PROPULSION SYSTEM TEST AND EVALUATION.(U)
SEP 79 E REIMERS DOE-IAA-EC-77-A-31-1042

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EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22 10:45:06 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	846.000	1052.000	1308.000	1638.000	2044.000	2558.000	3202.000
2	NO	RPM	60.000	162.000	222.000	294.000	372.000	472.000	596.000
3	TQ	FT-#	115.673	67.962	64.713	61.623	59.892	55.325	52.768
4	TO	Nm	165.455	98.826	95.189	91.548	87.880	82.495	80.415
5	TMOT	Nm	23.760	24.101	24.424	24.401	23.753	24.220	23.811
6	GEAR SELECT		2.000	2.000	2.000	2.000	2.000	2.000	2.000
7	GR RATIO:1		5.130	5.130	5.130	5.130	5.130	5.130	5.130
8	NSL	%	63.617	21.002	12.931	7.923	6.636	5.342	4.513
9	SL	RPS	8.970	3.682	2.819	2.163	2.261	2.277	2.409
10	PO	HP	1.394	2.248	2.968	3.780	4.591	5.468	6.731
11	PO	W	1039.621	1676.596	2213.019	2818.654	3423.534	4077.683	5019.085
12	PTR	HP	2.823	3.561	4.486	5.613	6.818	8.701	10.707
13	PTR	W	2105.022	2655.169	3345.570	4185.604	5084.514	6488.130	7984.320
14	TRANS EFF	%	49.388	63.145	66.148	67.342	67.333	62.848	62.862
15	WLTR	W/Nm	6.439	9.902	11.898	14.931	18.901	29.219	36.874
16	TRAN TEMP	C	64.982	62.981	62.024	56.748	53.789	50.743	49.084
17	MOTR TEMP	C	33.368	34.623	35.562	36.500	37.986	39.275	40.943

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 1121; S.N.: 1276

79-06-22 10:36:12 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	840.000	1048.000	1306.000	1642.000	2054.000	2556.000	3194.000
2	NO	RPM	120.000	176.000	232.000	298.000	378.000	476.000	598.000
3	TQ	FT-#	51.344	43.687	42.675	39.932	38.054	34.912	32.728
4	TO	Nm	70.405	63.563	58.450	55.862	52.300	47.916	45.360
5	TMOT	Nm	17.896	18.071	17.957	17.819	17.731	17.960	17.917
6	GEAR SELECT		2.000	2.000	2.000	2.000	2.000	2.000	2.000
7	GR RATIO:1		5.130	5.130	5.130	5.130	5.130	5.130	5.130
8	NSL	%	26.714	13.847	8.870	6.898	5.592	4.465	3.953
9	SL	RPS	3.740	2.419	1.931	1.888	1.914	1.902	2.104
10	PO	HP	1.186	1.571	1.904	2.338	2.776	3.203	3.809
11	PO	W	884.770	1171.543	1420.089	1743.307	2070.318	2388.534	2840.630
12	PTR	HP	2.111	2.660	3.293	4.109	5.115	6.447	8.037
13	PTR	W	1574.286	1983.253	2455.921	3064.046	3813.901	4807.291	5992.987
14	TRANS EFF	%	56.201	59.072	57.823	56.896	54.283	49.686	47.399
15	WLTR	W/Nm	9.794	12.770	17.722	23.643	33.338	50.479	69.497
16	TRAN TEMP	C	75.769	74.187	70.919	66.478	63.073	61.019	57.071
17	MOTR TEMP	C	40.491	41.680	42.274	42.914	43.175	44.121	45.254

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121J; S.N.: 1276

79-06-22   10:29:34   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	836.000	1044.000	1312.000	1638.000	2050.000	2556.000	3204.000
2	NO	RPM	140.000	184.000	240.000	302.000	382.000	478.000	602.000
3	TQ	FT-#	23.340	23.633	21.529	18.373	15.723	14.405	11.915
4	TO	Nm	34.469	34.001	31.154	27.524	22.333	18.558	15.300
5	TMOT	Nm	11.945	12.105	11.966	12.038	11.812	11.919	11.939
6	GEAR SELECT		2.000	2.000	2.000	2.000	2.000	2.000	2.000
7	GR RATIO:1		5.130	5.130	5.130	5.130	5.130	5.130	5.130
8	NSL	%	14.091	9.586	6.159	5.418	4.407	4.063	3.612
9	SL	RPS	1.963	1.668	1.347	1.479	1.506	1.731	1.929
10	PO	HP	0.678	0.879	1.050	1.167	1.198	1.246	1.294
11	PO	W	505.352	655.164	783.019	870.490	893.434	928.982	964.578
12	PTR	HP	1.402	1.775	2.205	2.769	3.401	4.278	5.372
13	PTR	W	1045.812	1323.504	1644.130	2064.905	2535.919	3190.375	4006.064
14	TRANS EFF	%	48.322	49.502	47.625	42.156	35.231	29.118	24.078
15	WLTR	W/Nm	15.680	19.657	27.640	43.395	73.544	121.854	198.787
16	TRAN TEMP	C	80.777	79.098	76.748	71.928	67.270	64.596	61.316
17	MOTR TEMP	C	40.086	41.229	41.467	41.514	41.918	42.131	42.464

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 1121; S.N.: 1276

79-06-22 10:26:35 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1236.000	2054.000	2556.000	3210.000
2	NO	RPM	272.000	530.000	674.000	856.000
3	TQ	FT-#	65.046	67.509	68.961	66.484
4	TO	Nm	94.789	100.637	99.748	99.038
5	TMOT	Nm	33.179	37.253	37.535	37.630
6	GEAR SELECT		3.000	3.000	3.000	3.000
7	GR RATIO:1		3.560	3.560	3.560	3.560
8	NSL	%	21.657	8.140	6.125	5.067
9	SL	RPS	4.461	2.787	2.609	2.711
10	PO	HP	3.621	7.491	9.442	11.906
11	PO	W	2700.035	5585.695	7040.540	8878.130
12	PTR	HP	5.759	10.746	13.473	16.964
13	PTR	W	4294.679	8013.109	10047.186	12649.809
14	TRANS EFF	%	62.869	69.707	70.075	70.184
15	WLTR	W/Nm	16.823	24.120	30.143	38.083
16	TRAN TEMP	C	77.170	68.218	64.892	60.378
17	MOTR TEMP	C	51.419	54.229	56.287	57.854

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22 10:23:02 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	848.000	1034.000	1310.000	1638.000	2032.000	2556.000	3204.000
2	NO	RPM	54.000	178.000	310.000	416.000	532.000	678.000	858.000
3	TQ	FT-#	94.314	76.644	51.210	52.103	51.077	51.530	49.559
4	TO	Nm	142.202	114.293	76.400	76.380	75.199	75.339	70.783
5	TMOT	Nm	24.223	29.550	29.407	29.718	29.481	30.084	29.678
6	GEAR SELECT		3.000	3.000	3.000	3.000	3.000	3.000	3.000
7	GR RATIO:1		3.560	3.560	3.560	3.560	3.560	3.560	3.560
8	NSL	%	77.330	38.716	15.756	9.587	6.795	5.568	4.667
9	SL	RPS	10.929	6.672	3.440	2.617	2.301	2.372	2.492
10	PO	HP	1.078	2.857	3.326	4.462	5.618	7.173	8.529
11	PO	W	804.160	2130.514	2480.270	3327.476	4189.538	5349.262	6360.037
12	PTR	HP	2.885	4.291	5.410	6.836	8.413	10.799	13.354
13	PTR	W	2151.174	3199.775	4034.328	5097.765	6273.552	8052.676	9958.071
14	TRANS EFF	%	37.382	66.583	61.479	65.273	66.781	66.428	63.868
15	WLTR	W/Nm	9.473	9.355	20.341	23.177	27.713	35.883	50.832
16	TRAN TEMP	C	78.744	76.437	69.683	65.368	64.165	60.035	55.941
17	MOTR TEMP	C	41.157	42.914	45.160	46.550	47.795	49.177	51.139

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 1121; S.N.: 1276

79-06-22 10:20:15 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	842.000	1046.000	1314.000	1642.000	2048.000	2554.000	3194.000
2	NO	RPM	54.000	228.000	326.000	424.000	540.000	682.000	860.000
3	TQ	FT-#	93.848	46.283	36.949	38.267	36.163	34.366	32.328
4	TO	Nm	138.905	65.733	56.565	58.975	53.505	53.877	52.202
5	TMOT	Nm	23.927	24.257	23.732	24.159	23.857	23.777	24.024
6	GEAR SELECT		3.000	3.000	3.000	3.000	3.000	3.000	3.000
7	GR RATIO:1		3.560	3.560	3.560	3.560	3.560	3.560	3.560
8	NSL	%	77.169	22.402	11.677	8.073	6.133	4.937	4.145
9	SL	RPS	10.829	3.905	2.557	2.209	2.093	2.101	2.207
10	PO	HP	1.053	2.105	2.590	3.512	4.058	5.160	6.305
11	PO	W	785.517	1569.509	1931.108	2618.663	3025.759	3848.002	4701.396
12	PTR	HP	2.829	3.563	4.379	5.571	6.862	8.528	10.776
13	PTR	W	2109.793	2657.166	3265.724	4154.329	5116.757	6359.410	8035.757
14	TRANS EFF	%	37.232	59.067	59.133	63.035	59.134	60.509	58.506
15	WLTR	W/Nm	9.534	16.547	23.595	26.039	39.080	46.613	63.875
16	TRAN TEMP	C	77.436	70.941	64.006	61.590	59.439	56.449	53.186
17	MOTR TEMP	C	41.870	42.559	43.743	44.310	45.514	46.385	47.490

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22 10:17:16 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	838.000	1050.000	1300.000	1640.000	2048.000	2556.000	3216.000
2	NO	RPM	170.000	252.000	332.000	430.000	546.000	686.000	864.000
3	TQ	FT-#	28.879	23.100	21.183	21.622	19.132	20.850	18.253
4	TO	Nm	46.757	37.205	34.303	35.584	33.206	33.029	30.375
5	TMOT	Nm	17.709	17.828	17.820	18.116	17.996	18.142	18.025
6	GEAR	SELECT	3.000	3.000	3.000	3.000	3.000	3.000	3.000
7	GR	RATIO:1	3.560	3.560	3.560	3.560	3.560	3.560	3.560
8	NSL	%	27.780	14.560	9.083	6.659	5.090	4.454	4.358
9	SL	RPS	3.880	2.548	1.968	1.820	1.737	1.897	2.336
10	PO	HP	1.116	1.317	1.599	2.149	2.546	3.182	3.686
11	PO	W	832.422	981.856	1192.656	1602.400	1898.661	2372.786	2748.392
12	PTR	HP	2.084	2.629	3.253	4.172	5.176	6.512	8.141
13	PTR	W	1554.128	1960.378	2426.089	3111.287	3859.605	4856.192	6070.642
14	TRANS	EFF %	53.562	50.085	49.160	51.503	49.193	48.861	45.274
15	WLTR	W/Nm	15.435	26.301	35.957	42.403	59.055	75.189	109.373
16	TRAN	TEMP C	58.061	55.363	51.908	50.439	48.967	47.654	47.537
17	MOTR	TEMP C	36.212	37.579	38.322	38.656	39.182	40.324	42.226

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 1121J; S.N.: 1276

79-06-22 10:14:19 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	840.000	1052.000	1314.000	1636.000	2056.000	2568.000	3226.000
2	NO	RPM	204.000	270.000	346.000	436.000	554.000	696.000	876.000
3	TQ	FT-#	2.181	0.743	0.456	0.323	0.616	1.055	3.731
4	TO	Nm	5.761	3.750	1.598	3.248	1.414	0.272	0.080
5	TMOT	Nm	12.087	11.814	12.004	12.097	12.187	11.861	12.129
6	GEAR	SELECT	3.000	3.000	3.000	3.000	3.000	3.000	3.000
7	GR	RATIO:1	3.560	3.560	3.560	3.560	3.560	3.560	3.560
8	NSL	%	13.543	8.631	6.259	5.125	4.074	3.514	3.330
9	SL	RPS	1.896	1.513	1.371	1.397	1.396	1.504	1.791
10	PO	HP	0.165	0.142	0.078	0.199	0.110	0.027	0.010
11	PO	W	123.086	106.036	57.896	148.324	82.041	19.814	7.338
12	PTR	HP	1.426	1.745	2.215	2.779	3.519	4.278	5.495
13	PTR	W	1063.229	1301.546	1651.829	2072.565	2624.005	3189.797	4097.542
14	TRANS EFF	%	11.577	8.147	3.505	7.157	3.127	0.621	0.179
15	WLTR	W/Nm	163.178	318.790	997.574	592.348	1797.584	11661.301	51316.006
16	TRAN TEMP	C	38.919	39.752	39.776	39.538	39.395	39.538	39.943
17	MOTR TEMP	C	27.288	29.754	30.945	31.528	32.110	32.739	33.851

EVA TRANSMISSION TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121l; S.N.: 1276

79-06-22   10:10:12   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM
2	NO	RPM
3	TQ	FT-#
4	TO	Nm
5	TMOT	Nm
6	GEAR	SELECT
7	GR	RATIO:1
8	NSL	%
9	SL	RPS
10	PO	HP
11	PO	W
12	PTR	HP
13	PTR	W
14	TRANS	EFF %
15	WLTR	W/Nm
16	TRAN	TEMP C
17	MOTR	TEMP C

APPENDIX C

EVA DC MOTOR TEST ROUTINE, SOFTWARE DATA, PRINT-OUT AND CALCULATED PERFORMANCE

```
0: dsp "EVA DC MOTOR TEST, CHOPPER DRIVEN"
1: dsp "PROGRAM TAPE TRACK 0, FILE 25"
2: dsp "PROGRAM UPDATE: 5-2-79"
3: clr 7
4: dim A[36,10];dim B[36,10];dim C$[13]
5: dsp "PUT DATA TAPE IN CALCULATOR";stp
6: enp "DATA TAPE TRACK: ",D;trk D
7: enp "FIRST RAW DATA  FILE = ",G;gto "data"
8: "avg 1":
9: wrt 722,"B;U=>";wait 100;trg 722
10: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
11: I+1→I;ret
12: "avg 10":
13: wrt 722,"B;U;>";wait 100;trg 722
14: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
15: I+1→I;ret
16: "avg 100":
17: wrt 722,"B;U7>";wait 100;trg 722
18: red 722.2,A[I,P];clr 722
19: I+1→I;ret
20: "rms 1":
21: wrt 722,"B;U==";wait 100;trg 722
22: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
23: I+1→I;ret
24: "rms 10":
25: wrt 722,"B;U;=";wait 100;trg 722
26: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
27: I+1→I;ret
28: "rms 100":
29: wrt 722,"B;U7=";wait 100;trg 722
30: red 722.2,A[I,P];clr 722
31: I+1→I;ret
32: dsp "CLOCK READ AND PRINT, NO CR/LF"
33: "clockread":
34: fmt 8,c1;wrt 708.8,"C";fmt 8,c12;red 708.8,C$;clr 708;ret
35: "clockprint":
36: fmt 1,c2,z;fmt 2,"-",z;fmt 3,":",z
37: fmt 4,5x,z;fmt 5,3/;fmt 6,"79-",z;wrt 715.5
38: wrt 715.6;wrt 715.1,C$[3,4];wrt 715.2;wrt 715.1,C$[5,6]
39: wrt 715.4;wrt 715.1,C$[7,8];wrt 715.3;wrt 715.1,C$[9,10]
40: wrt 715.3;wrt 715.1,C$[11,12];wrt 715.4;ret
41: "poly":
42: if p0<11;gto +2
43: (((((((p1p18+p17)p1+p16)p1+p15)p1+p14)p1+p13)p1+p12)p1+p11)p1→p20
44: ((((((((p20+p10)p1+p9)p1+p8)p1+p7)p1+p6)p1+p5)p1+p4)p1+p3)p1→p20
45: ret p20+p2
46: "*temp T":
47: if p2>0;gto +8
48: 0→p3;3.874077384e1→p4;4.4123932482e-2→p5;1.1405238498e-4→p6
49: 1.9974406568e-5→p7;9.0445401187e-7→p8;2.2766018504e-8→p9
50: 3.624740938e-10→p10;3.8648924201e-12→p11;2.8298678519e-14→p12
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51: 1.4281383349e-16→p13;4.8833254364e-19→p14;1.0803474683e-21→p15
52: 1.3949291026e-24→p16;7.9795893156e-28→p17;if p24>0;gto +10
53: 'poly'(p2,p3,p4,p5,p6,p7,p8,p9,p10,p11,p12,p13,p14,p15,p16,p17)→p20
54: p20/1e6+p1→p20;gto +5
55: 0→p3;3.874077384e1→p4;3.3190198092e-2→p5;2.0714183645e-4→p6
56: -2.1945834823e-6→p7;1.103190055e-8→p8;-3.0927581898e-11→p9
57: 4.5653337165e-14→p10;-2.761687804e-17→p11;if p24>0;gto +11
58: 'poly'(p2,p3,p4,p5,p6,p7,p8,p9,p10,p11)/1e6+p1→p20
59: .002→p21
60: 1→p24;if p20>0;gto -5
61: gto -13
62: 'poly'(p21,p3,p4,p5,p6,p7,p8,p9,p10,p11,p12,p13,p14,p15,p16,p17)/1e6→p22
63: p22-p20→p22
64: if abs(p22)<.0000001;ret p21
65: 'poly'(p21,0,0,0,0,0,0,7p10,8p11,9p12,10p13,11p14,12p15,13p16,14p17)→p23
66: (p23+'poly'(p21,p4,2p5,3p6,4p7,5p8,6p9))/1e6→p23
67: p21-p22/p23→p21;gto -5
68: 'poly'(p21,p3,p4,p5,p6,p7,p8,p9,p10,p11)/1e6-p20→p22
69: if abs(p22)<.0000001;ret p21
70: 'poly'(p21,p4,2p5,3p6,4p7,5p8,6p9,7p10,8p11)/1e6→p23
71: p21-p22/p23→p21;gto -3
72: "data":
73: dsp "PRESS CONTINUE TO CLEAR ARRAYS";stp
74: for I=1 to 34
75: for J=1 to 10
76: 0→A[I,J]
77: next J
78: next I
79: for I=1 to 34
80: for J=1 to 10
81: 0→B[I,J]
82: next J
83: next I
84: 0→H
85: dsp "PRESS CONTINUE TO READ DATA";stp
86: for P=1 to 10
87: H+1→H;1→I
88: fmt 1,3x,e14.4;fmt 2,e13.6,z;fmt 5,f3.0
89: wrt 709.5,"C",34;wait 100
90: wrt 714,"I"
91: time 2000
92: on err "T1"
93: red 714.1,A[I,P];jmp 2
94: "T1":0→A[I,P];dsp "NO MOTOR SPEED";jmp 2
95: dsp "MOTOR SPEED MEASURED"
96: clr 709;I+1→I
97: wrt 709.5,"C",1
98: gsb "avg 10"
99: for Q=10 to 12
100: wrt 709.5,"C",Q
101: gsb "avg 100"
102: next Q
103: wrt 709.5,"C",20
104: gsb "avg 1"
```

```
105: wrt 709.5,"C",21
106: gsb "avg 1"
107: wrt 709.5,"C",23
108: gsb "avg 1"
109: wrt 709.5,"C",24
110: gsb "avg 1"
111: wrt 709.5,"C",28
112: gsb "avg 1"
113: wrt 709.5,"C",13
114: gsb "avg 1"
115: wrt 709.5,"C",14
116: gsb "avg 1"
117: wrt 709.5,"C",16
118: gsb "avg 1"
119: wrt 709.5,"C",17
120: gsb "avg 1"
121: wrt 709.5,"C",18
122: gsb "avg 1"
123: wrt 709.5,"C",6
124: gsb "avg 1"
125: wrt 709.5,"C",35;wait 100
126: wrt 714,"I"
127: time 2000
128: on err "T2"
129: red 714.1,A[I,P];jmp 2
130: "T2":0→A[I,P];dsp "NO CHOPPER SIGNAL";jmp 2
131: dsp "CHOPPER PERIOD MEASURED"
132: clr 709;I+1→I
133: for Q=10 to 12
134: wrt 709.5,"C",Q
135: gsb "rms 100"
136: next Q
137: wrt 709.5,"C",20
138: gsb "rms 1"
139: wrt 709.5,"C",21
140: gsb "rms 1"
141: for Q=23 to 28
142: wrt 709.5,"C",Q
143: gsb "rms 1"
144: next Q
145: for Q=13 to 18
146: wrt 709.5,"C",Q
147: gsb "rms 1"
148: next Q
149: wrt 709.5,"C",29
150: gsb "rms 1"
151: gsb "avg 1"
152: dsp "MEASUREMENTS COMPLETE";wait 1000;clr 7
153: dsp "NEW TORQUE SETTING?";wait 2500
154: dsp "PRESS CONTINUE WHEN READY";stp
155: next P
156: "record A":
157: dsp "PRESS CONTINUE TO RECORD A-ARRAY";stp
158: [illegible] G,A[*]
```

```
159: G+1→G;1→I
160: "convert":
161: dsp "CONVERT TO TRUE DATA"
162: on err "E2";jmp 3
163: "E2":dsp "ERROR IN CONVERT ROUTINE";stp
164: fxd 0;dsp "ERROR ",char(rom),ern,"IN LINE ",erl;stp
165: for P=1 to H
166: if A[1,P]=0;1→B[1,P];jmp 2
167: 2/A[1,P]→B[1,P]
168: 8.333*A[2,P]→B[2,P]
169: A[3,P]→B[3,P]
170: A[4,P]→B[4,P]
171: A[5,P]→B[5,P]
172: 2000*1.003*A[6,P]→B[6,P]
173: 2000*.9766*A[7,P]→B[7,P]
174: 2000*1.011*A[8,P]→B[8,P]
175: 2000*1.007*A[9,P]→B[9,P]
176: A[10,P]→B[10,P]
177: A[11,P]→B[11,P]
178: A[12,P]→B[12,P]
179: 200*1.003*1.033*A[13,P]→B[13,P]
180: 1600*1.003/1.03*A[14,P]→B[14,P]
181: 100*1.003*.983*A[15,P]→B[15,P]
182: ´*temp T´(A[16,P])→B[16,P]
183: if A[17,P]=0;1→B[17,P];jmp 2
184: 1/A[17,P]→B[17,P]
185: A[18,P]→B[18,P]
186: A[19,P]→B[19,P]
187: A[20,P]→B[20,P]
188: 2000*1.003*A[21,P]→B[21,P]
189: 2000*.9766*A[22,P]→B[22,P]
190: 2000*1.011*A[23,P]→B[23,P]
191: 2000*1.007*A[24,P]→B[24,P]
192: 2000*1.003*A[25,P]→B[25,P]
193: 400*A[26,P]→B[26,P]
194: 400*A[27,P]→B[27,P]
195: for I=28 to 31
196: A[I,P]→B[I,P]
197: next I
198: 200*1.003*1.033*A[32,P]→B[32,P]
199: 1600*1.003/1.03*A[33,P]→B[33,P]
200: 100*1.003*.983*A[34,P]→B[34,P]
201: A[35,P]→B[35,P]
202: A[36,P]→B[36,P]
203: next P
204: "record B":
205: dsp "PRESS CONTINUE TO RECORD B-ARRAY";stp
206: rcf G,B[*]
207: G+1→G
208: dsp "IS PAPER POSITIONED PROPERLY?";stp
209: "print":
210: 0→R
211: dsp "SET R=1 TO PRINT";wait 1000
212: ent "R= ",R;if R#1;gto "data"
```

```
213: dsp "IS PAPER POSITIONED PROPERLY?";stp
214: "SET TOP OF FORM":
215: wtb 715,27,84
216: wrt 715,"EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE"
217: wrt 715,"DC SERIES MOTOR, 10 HP, 3800 RPM"
218: wrt 715,"BALDOR ELECTRIC CO., ST. LOUIS, MO"
219: wrt 715,"SPEC: 29 1755 1121; S.N.: 1276"
220: gsb "clockread"
221: gsb "clockprint"
222: wrt 715,"MERADCOM, DRDME-EA, FT. BELVOIR, VA  22060";wrt 715.5
223: dsp "HEADER AND DATE/TIME PRINTED"
224: fmt 4,f2.0,z;fmt 6,x,f9.3,z;fmt 9,2x,c11,z
225: 37→M
226: for I=1 to M-1
227: wrt 715.4,I
228: jmp I
229: wrt 715.9,"NTR      RPM";jmp M-I
230: wrt 715.9,"TMOT    FT-#";jmp M-I
231: wrt 715.9,"EBAT     VDC";jmp M-I
232: wrt 715.9,"EARM     VDC";jmp M-I
233: wrt 715.9,"EFM      VDC";jmp M-I
234: wrt 715.9,"IBAT´    ADC";jmp M-I
235: wrt 715.9,"IARM     ADC";jmp M-I
236: wrt 715.9,"ITH1     ADC";jmp M-I
237: wrt 715.9,"ID2      ADC";jmp M-I
238: wrt 715.9,"VCT1     VDC";jmp M-I
239: wrt 715.9,"ETH1     VDC";jmp M-I
240: wrt 715.9,"EDF2     VDC";jmp M-I
241: wrt 715.9,"PLABT      W";jmp M-I
242: wrt 715.9,"PLACOM     W";jmp M-I
243: wrt 715.9,"PLAC4      W";jmp M-I
244: wrt 715.9,"MOTR TEMP C";jmp M-I
245: wrt 715.9,"CONTROLR HZ";jmp M-I
246: wrt 715.9,"EBAT    VRMS";jmp M-I
247: wrt 715.9,"EARM    VRMS";jmp M-I
248: wrt 715.9,"EFM     VRMS";jmp M-I
249: wrt 715.9,"IBAT´   ARMS";jmp M-I
250: wrt 715.9,"IARM    ARMS";jmp M-I
251: wrt 715.9,"ITH1    ARMS";jmp M-I
252: wrt 715.9,"ID2     ARMS";jmp M-I
253: wrt 715.9,"IC4     ARMS";jmp M-I
254: wrt 715.9,"ITH2    ARMS";jmp M-I
255: wrt 715.9,"ID4     ARMS";jmp M-I
256: wrt 715.9,"VCT1    VRMS";jmp M-I
257: wrt 715.9,"ETH1    VRMS";jmp M-I
258: wrt 715.9,"EDF2    VRMS";jmp M-I
259: wrt 715.9,"VC4     VRMS";jmp M-I
260: wrt 715.9,"PLBT       W";jmp M-I
261: wrt 715.9,"PLCOM      W";jmp M-I
262: wrt 715.9,"PLC4       W";jmp M-I
263: wrt 715.9,"VINT    VRMS";jmp M-I
264: wrt 715.9,"VINT     VDC";jmp M-I
265: for P=1 to H
266: wrt 715.6,abs(B[I,P])
```

```
267: next P
268: wrt 715," "
269: next I
270: "form feed":
271: wtb 715,12
272: "raw data":
273: dsp "PRINT RAW DATA?";stp
274: wrt 715,"EVA DC MOTOR TEST RAW DATA"
275: wrt 715,"CHOPPER WITH BUFFERED BATTERY SOURCE"
276: fmt 3,c14,f3.0;wrt 715.3,"DATA ON FILE: ",G-2
277: gsb "clockprint"
278: wrt 715.5;fmt 4,f2.0,z;fmt 6,x,f9.4,z
279: fmt 9,2x,c11,z
280: 37→M
281: for I=1 to M-1
282: wrt 715.4,I
283: jmp I
284: wrt 715.9,"SPD SIG PER";jmp M-I
285: wrt 715.9,"TMOT    VDC";jmp M-I
286: wrt 715.9,"EBAT    VDC";jmp M-I
287: wrt 715.9,"EARM    VDC";jmp M-I
288: wrt 715.9,"EFM     VDC";jmp M-I
289: wrt 715.9,"IBAT    VDC";jmp M-I
290: wrt 715.9,"IARM    VDC";jmp M-I
291: wrt 715.9,"ITH1    VDC";jmp M-I
292: wrt 715.9,"ID2     VDC";jmp M-I
293: wrt 715.9,"VCT1    VDC";jmp M-I
294: wrt 715.9,"ETH1    VDC";jmp M-I
295: wrt 715.9,"EDF2    VDC";jmp M-I
296: wrt 715.9,"PLABT   VDC";jmp M-I
297: wrt 715.9,"PLACOM  VDC";jmp M-I
298: wrt 715.9,"PLAC4   VDC";jmp M-I
299: wrt 715.9,"TEMPM   VDC";jmp M-I
300: wrt 715.9,"CHP SIG PER";jmp M-I
301: wrt 715.9,"EBAT   VRMS";jmp M-I
302: wrt 715.9,"EARM   VRMS";jmp M-I
303: wrt 715.9,"EFM    VRMS";jmp M-I
304: wrt 715.9,"IBAT   VRMS";jmp M-I
305: wrt 715.9,"IARM   VRMS";jmp M-I
306: wrt 715.9,"ITH1   VRMS";jmp M-I
307: wrt 715.9,"ID2    VRMS";jmp M-I
308: wrt 715.9,"IC4    VRMS";jmp M-I
309: wrt 715.9,"ITH2   VRMS";jmp M-I
310: wrt 715.9,"ID4    VRMS";jmp M-I
311: wrt 715.9,"VCT1   VRMS";jmp M-I
312: wrt 715.9,"ETH1   VRMS";jmp M-I
313: wrt 715.9,"EDF2   VRMS";jmp M-I
314: wrt 715.9,"VC4    VRMS";jmp M-I
315: wrt 715.9,"PLBT   VRMS";jmp M-I
316: wrt 715.9,"PLCOM  VRMS";jmp M-I
317: wrt 715.9,"PLC4   VRMS";jmp M-I
318: wrt 715.9,"VINT   VRMS";jmp M-I
319: wrt 715.9,"VINT    VDC";jmp M-I
320: for P=1 to H
```

```
321: wrt 715.6,A[I,P]
322: next P
323: wrt 715," "
324: next I
325: wtb 715,12
326: gto "data"
327: end
*25293
```

```
0: dsp "FILE 37, TRACK 1, PROGRAM TAPE"
1: dsp "EVA DC MOTOR CHOPPER DRIVE DATA REDUCTION"
2: dsp "PROGRAM UPDATE: 5-11-79"
3: dim B[36,10];dim C[43,10];dim C$[13];dim Q[10]
4: enp "DATA TAPE TRACK:",T;trk T
5: enp "FIRST DATA FILE:",F
6: enp "LAST DATA FILE:",L
7: enp "FIRST REDUCED DATA FILE:",N
8: for K=F to L by 2
9: for I=1 to 36
10: for J=1 to 10
11: 0→B[I,J]
12: next J
13: next I
14: ldf K,B[*]
15: wait 50
16: for I=1 to 36
17: for J=1 to 10
18: abs(B[I,J])→B[I,J]
19: next J
20: next I
21: dsp "ALL DATA POSITIVE";wait 500
22: for I=1 to 36
23: for J=1 to 10
24: if B[I,J]<0;prt "I=",I;prt "J=",J;spc 1
25: next J
26: next I
27: dsp "DATA LOADED, CONTINUE?";stp
28: for I=1 to 43
29: for J=1 to 10
30: 0→C[I,J]
31: next J
32: next I
33: for I=1 to 10
34: 0→Q[I]
35: next I
36: 0→R→S
37: for P=1 to 10
38: if B[1,P]=0;P-1→S;gto "record C"
39: if B[1,P]=1;P→S;gto "last calculation"
40: if P=10;P→S
41: B[1,P]→C[1,P]
42: B[2,P]→C[2,P]
43: B[2,P]*1.3558→C[3,P]
44: (B[7,P]^2/.9766+B[8,P]^2/1.011)/2000→Q[1]
45: B[6,P]^2/1.003/2000→Q[2]
46: (B[22,P]^2/.9766+B[23,P]^2/1.011)/2000→Q[3]
47: B[21,P]^2/1.003/2000→Q[4]
48: B[3,P]*B[6,P]-Q[1]-Q[2]→C[4,P]
49: C[4,P]/B[3,P]→C[5,P]
50: B[18,P]*B[21,P]-Q[3]-Q[4]→C[6,P]
```

```
51: C[6,P]/B[18,P]→C[7,P]
52: (C[5,P]/C[7,P])^2→C[8,P]
53: 1-C[8,P]→C[9,P]
54: B[5,P]+B[12,P]+B[9,P]*(1/.9766+1/1.007)/2000→C[10,P]
55: (B[4,P]+C[10,P])*B[7,P]→C[11,P]
56: 745.7*B[1,P]*B[2,P]/5252→C[12,P]
57: B[22,P]^2*(B[4,P]+B[5,P])/B[7,P]+B[24,P]*B[30,P]→Q[5]
58: Q[5]+B[24,P]^2*((1/.9766)^2+(1/1.007)^2)/2000→C[13,P]
59: 100*C[12,P]/C[11,P]→C[14,P]
60: (C[11,P]-C[12,P])/C[3,P]→C[15,P]
61: 100*C[12,P]/C[13,P]→C[16,P]
62: (C[13,P]-C[12,P])/C[3,P]→C[17,P]
63: 100*(1-C[16,P]/C[14,P])→C[18,P]
64: C[13,P]-C[12,P]→C[19,P]
65: C[6,P]-C[13,P]-Q[3]→C[20,P]
66: B[7,P]*B[10,P]→C[21,P]
67: B[22,P]*B[28,P]→C[22,P]
68: C[11,P]*B[22,P]/B[7,P]^2→C[23,P]
69: 100*C[13,P]/C[6,P]→C[24,P]
70: C[20,P]/C[3,P]→C[25,P]
71: B[8,P]*B[11,P]→C[26,P]
72: B[9,P]*B[12,P]→C[27,P]
73: B[23,P]*B[29,P]→C[28,P]
74: B[24,P]*B[30,P]→C[29,P]
75: C[20,P]-C[28,P]-C[29,P]-C[22,P]→C[30,P]
76: -B[6,1]*(B[3,1]-B[3,2])/(B[6,1]-B[6,2])+B[3,1]→C[41,P]
77: C[41,P]-B[3,P]→C[40,P]
78: C[40,P]*C[5,P]→C[31,P]
79: C[40,P]/C[5,P]*C[7,P]^2→C[32,P]
80: C[4,P]+C[31,P]→C[33,P]
81: 100*C[12,P]/C[33,P]→C[34,P]
82: C[6,P]+C[32,P]→C[35,P]
83: 100*C[12,P]/C[35,P]→C[36,P]
84: C[35,P]/C[12,P]-1→C[37,P]
85: C[19,P]+C[20,P]→C[38,P]
86: 100*(1-C[36,P]/C[34,P])→C[39,P]
87: C[4,P]-C[11,P]-Q[1]→C[42,P]
88: C[42,P]-C[26,P]-C[27,P]-C[21,P]→C[43,P]
89: "last calculation":
90: next P
91: dsp "DATA REDUCTION COMPLETED!";wait 1000
92: "record C":
93: trk 0
94: dsp "IS REDUCED DATA TAPE IN CALC.?";stp
95: dsp "PRESS CONTINUE TO RECORD C-ARRAY";stp
96: rcf N,C[*]
97: N+1→N
98: trk 1
99: "clockread":
100: fmt 8,c1;wrt 708.8,"C";fmt 8,c12;red 708.8,C$;clr 708
101: "print":
102: dsp "IS PAPER POSITIONED PROPERLY?";stp
103: "SET TOP OF FORM":
104: wtb 715,27,84
```

```
105: wrt 715,"EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE"
106: "clockprint":
107: fmt 1,c2,z;fmt 2,"-",z;fmt 3,":",z
108: fmt 4,5x,z;fmt 5,2/;fmt 6,"79-",z;wrt 715.5
109: wrt 715.6;wrt 715.1,C$[3,4];wrt 715.2;wrt 715.1,C$[5,6]
110: wrt 715.4;wrt 715.1,C$[7,8];wrt 715.3;wrt 715.1,C$[9,10]
111: wrt 715.3;wrt 715.1,C$[11,12];wrt 715.4
112: wrt 715,"MERADCOM, DRDME-EA, FT. BELVOIR, VA  22060"
113: wrt 715.5;dsp "HEADER AND DATE/TIME PRINTED"
114: fmt 4,f2.0,z;fmt 6,2x,f9.3,z;fmt 9,2x,c11,z
115: 44→M
116: for I=1 to M-1
117: wrt 715.4,I
118: jmp I
119: wrt 715.9,"NTR      RPM";jmp M-I
120: wrt 715.9,"TMOT    FT-#";jmp M-I
121: wrt 715.9,"TMOT     N-m";jmp M-I
122: wrt 715.9,"PABAT      W";jmp M-I
123: wrt 715.9,"IBAT     ADC";jmp M-I
124: wrt 715.9,"PBAT       W";jmp M-I
125: wrt 715.9,"IBAT    ARMS";jmp M-I
126: wrt 715.9,"DELTAMOT PU";jmp M-I
127: wrt 715.9,"DELTAD2   PU";jmp M-I
128: wrt 715.9,"DFM      VDC";jmp M-I
129: wrt 715.9,"PAMOT      W";jmp M-I
130: wrt 715.9,"PTR        W";jmp M-I
131: wrt 715.9,"PMOT       W";jmp M-I
132: wrt 715.9,"EFFAMOT    %";jmp M-I
133: wrt 715.9,"WLAMT W/N-m";jmp M-I
134: wrt 715.9,"EFFMOT     %";jmp M-I
135: wrt 715.9,"WLMOT W/N-m";jmp M-I
136: wrt 715.9,"DEGM       %";jmp M-I
137: wrt 715.9,"PLMOT      W";jmp M-I
138: wrt 715.9,"PLCTR      W";jmp M-I
139: wrt 715.9,"PACT       W";jmp M-I
140: wrt 715.9,"PCT        W";jmp M-I
141: wrt 715.9,"EMOT    VRMS";jmp M-I
142: wrt 715.9,"EFFCTR     %";jmp M-I
143: wrt 715.9,"WLCTR W/N-m";jmp M-I
144: wrt 715.9,"PATH1      W";jmp M-I
145: wrt 715.9,"PAD2F      W";jmp M-I
146: wrt 715.9,"PTH1       W";jmp M-I
147: wrt 715.9,"PD2F       W";jmp M-I
148: wrt 715.9,"PLCOM      W";jmp M-I
149: wrt 715.9,"PLABT      W";jmp M-I
150: wrt 715.9,"PLBAT      W";jmp M-I
151: wrt 715.9,"PAEV       W";jmp M-I
152: wrt 715.9,"EFFAEV     %";jmp M-I
153: wrt 715.9,"PEV        W";jmp M-I
154: wrt 715.9,"EFFEV      %";jmp M-I
155: wrt 715.9,"WLEV      PU";jmp M-I
156: wrt 715.9,"PHEAT      W";jmp M-I
157: wrt 715.9,"DEGEV      %";jmp M-I
158: wrt 715.9,"DELTABT VDC";jmp M-I
```

```
159: wrt 715.9,"EBATO    VDC";jmp M-I
160: wrt 715.9,"PLACTR     W";jmp M-I
161: wrt 715.9,"PLACOM     W";jmp M-I
162: for P=1 to S
163: wrt 715.6,C[I,P]
164: next P
165: wrt 715," "
166: next I
167: wtb 715,12
168: R+1→R
169: if R<2;gto "print"
170: next K
171: end
*21612
```

```
0: dsp "EVA DC MOTOR TEST ROUTINE"
1: dsp "PROGRAM TAPE TRACK 0, FILE 24"
2: dsp "PROGRAM UPDATE: 4-25-79"
3: clr 7
4: dim A[11,10];dim B[14,10];dim C$[13]
5: dsp "PUT DATA TAPE IN CALCULATOR";stp
6: enp "DATA TAPE TRACK: ",D;trk D
7: enp "FIRST RAW DATA  FILE = ",G;gto "data"
8: "avg 1":
9: wrt 722,"B;U=>";wait 100;trg 722
10: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
11: I+1→I;ret
12: "avg 10":
13: wrt 722,"B;U;>";wait 100;trg 722
14: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
15: I+1→I;ret
16: "avg 100":
17: wrt 722,"B;U7>";wait 100;trg 722
18: red 722.2,A[I,P];clr 722
19: I+1→I;ret
20: "rms 1":
21: wrt 722,"B;U==";wait 100;trg 722
22: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
23: I+1→I;ret
24: "rms 10":
25: wrt 722,"B;U;=";wait 100;trg 722
26: red 722.2,A[I,P];clr 722;if A[I,P]>1000;jmp 2
27: I+1→I;ret
28: "rms 100":
29: wrt 722,"B;U7=";wait 100;trg 722
30: red 722.2,A[I,P];clr 722
31: I+1→I;ret
32: dsp "CLOCK READ AND PRINT, NO CR/LF"
33: "clockread":
34: fmt 8,c1;wrt 708.8,"C";fmt 8,c12;red 708.8,C$;clr 708;ret
35: "clockprint":
36: fmt 1,c2,z;fmt 2,"-",z;fmt 3,":",z
37: fmt 4,5x,z;fmt 5,3/;fmt 6,"79-",z;wrt 715.5
38: wrt 715.6;wrt 715.1,C$[3,4];wrt 715.2;wrt 715.1,C$[5,6]
39: wrt 715.4;wrt 715.1,C$[7,8];wrt 715.3;wrt 715.1,C$[9,10]
40: wrt 715.3;wrt 715.1,C$[11,12];wrt 715.4;ret
41: "poly":
42: if p0<11;gto +2
43: (((((((p1p18+p17)p1+p16)p1+p15)p1+p14)p1+p13)p1+p12)p1+p11)p1→p20
44: ((((((((p20+p10)p1+p9)p1+p8)p1+p7)p1+p6)p1+p5)p1+p4)p1+p3)p1→p20
45: ret p20→p2
46: "* temp T":
47: if p2>0;gto +8
48: 0→p3;3.874077384e1→p4;4.4123932482e-2→p5;1.1405238498e-4→p6
49: 1.9974406568e-5→p7;9.0445401187e-7→p8;2.2766018504e-8→p9
50: 3.624740938e-10→p10;3.8648924201e-12→p11;2.8298678519e-14→p12
```

```
51: 1.4281383349e-16→p13;4.8833254364e-19→p14;1.0803474683e-21→p15
52: 1.3949291026e-24→p16;7.9795893156e-28→p17;if p24>0;gto +10
53: 'poly'(p2,p3,p4,p5,p6,p7,p8,p9,p10,p11,p12,p13,p14,p15,p16,p17)→p20
54: p20/1e6+p1→p20;gto +5
55: 0→p3;3.874077384e1→p4;3.3190198092e-2→p5;2.0714183645e-4→p6
56: -2.1945834823e-6→p7;1.103190055e-8→p8;-3.0927581898e-11→p9
57: 4.5653337165e-14→p10;-2.761687804e-17→p11;if p24>0;gto +11
58: 'poly'(p2,p3,p4,p5,p6,p7,p8,p9,p10,p11)/1e6+p1→p20
59: .002→p21
60: 1→p24;if p20>0;gto -5
61: gto -13
62: 'poly'(p21,p3,p4,p5,p6,p7,p8,p9,p10,p11,p12,p13,p14,p15,p16,p17)/1e6→p22
63: p22-p20→p22
64: if abs(p22)<.0000001;ret p21
65: 'poly'(p21,0,0,0,0,0,0,7p10,8p11,9p12,10p13,11p14,12p15,13p16,14p17)→p23
66: (p23+'poly'(p21,p4,2p5,3p6,4p7,5p8,6p9))/1e6→p23
67: p21-p22/p23→p21;gto -5
68: 'poly'(p21,p3,p4,p5,p6,p7,p8,p9,p10,p11)/1e6-p20→p22
69: if abs(p22)<.0000001;ret p21
70: 'poly'(p21,p4,2p5,3p6,4p7,5p8,6p9,7p10,8p11)/1e6→p23
71: p21-p22/p23→p21;gto -3
72: "data":
73: dsp "PRESS CONTINUE TO CLEAR ARRAYS";stp
74: for I=1 to 11
75: for J=1 to 10
76: 0→A[I,J]
77: next J
78: next I
79: for I=1 to 14
80: for J=1 to 10
81: 0→B[I,J]
82: next J
83: next I
84: 0→H
85: dsp "PRESS CONTINUE TO READ DATA";stp
86: for P=1 to 10
87: H+1→H;1→I
88: fmt 1,3x,e14.4;fmt 2,e13.6,z;fmt 5,f3.0
89: wrt 709.5,"C",34;wait 100
90: wrt 714,"I"
91: time 1000
92: on err "T1"
93: red 714.1,A[I,P];jmp 2
94: "T1":0→A[I,P];dsp "NO MOTOR SPEED";jmp 2
95: dsp "MOTOR SPEED MEASURED"
96: clr 709;I+1→I
97: wrt 709.5,"C",1
98: gsb "avg 10"
99: for Q=10 to 12
100: wrt 709.5,"C",Q
101: gsb "avg 100"
102: next Q
103: wrt 709.5,"C",20
104: gsb "avg 1"
```

```
105: wrt 709.5,"C",6
106: gsb "avg 1"
107: for Q=10 to 12
108: wrt 709.5,"C",Q
109: gsb "rms 100"
110: next Q
111: wrt 709.5,"C",20
112: gsb "rms 1"
113: dsp "MEASUREMENTS COMPLETE";wait 1000;clr 7
114: dsp "NEW TORQUE SETTING?";wait 2500
115: dsp "PRESS CONTINUE WHEN READY";stp
116: next P
117: "record A":
118: dsp "PRESS CONTINUE TO RECORD A-ARRAY";stp
119: rcf G,A[*]
120: G+1→G;1→I
121: "convert":
122: dsp "CONVERT TO TRUE DATA"
123: on err "E2";jmp 3
124: "E2":dsp "ERROR IN CONVERT ROUTINE";stp
125: fxd 0;dsp "ERROR ",char(rom),ern,"IN LINE ",erl;stp
126: for P=1 to H
127: if A[1,P]=0;1→B[1,P];jmp 2
128: 2/A[1,P]→B[1,P]
129: 8.333*A[2,P]→B[2,P]
130: B[2,P]*1.3558→B[3,P]
131: for I=3 to 5
132: A[I,P]→B[I+1,P]
133: next I
134: 2000*1.003*A[6,P]→B[7,P]
135: 2000*1.003*A[11,P]→B[8,P]
136: '*temp T'(A[7,P])→B[9,P]
137: B[1,P]*B[2,P]/5252→B[10,P]
138: 745.7*B[10,P]→B[11,P]
139: B[4,P]*B[7,P]→B[12,P]
140: 100*B[11,P]/B[12,P]→B[13,P]
141: (B[12,P]-B[11,P])/B[3,P]→B[14,P]
142: next P
143: "record B":
144: dsp "PRESS CONTINUE TO RECORD B-ARRAY";stp
145: rcf G,B[*]
146: G+1→G
147: dsp "IS PAPER POSITIONED PROPERLY?";stp
148: "print":
149: wrt 715,"EVA DC MOTOR TEST WITH DC POWER SOURCE"
150: wrt 715,"DC SERIES MOTOR, 10 HP, 3800 RPM"
151: wrt 715,"BALDOR ELECTRIC CO., ST. LOUIS, MO"
152: wrt 715,"SPEC: 29 1755 1121; S.N.: 1276"
153: gsb "clockprint"
154: wrt 715,"MERADCOM, DRDME-EA, FT. BELVOIR, VA  22060";wrt 715.5
155: dsp "HEADER AND DATE/TIME PRINTED"
156: fmt 4,f2.0,z;fmt 6,x,f9.3,z;fmt 9,2x,c11,z
157: 15→M
158: for I=1 to M-1
```

```
159: wrt 715.4,I
160: jmp I
161: wrt 715.9,"NTR      RPM";jmp M-I
162: wrt 715.9,"TMOT    FT-#";jmp M-I
163: wrt 715.9,"TMOT      Nm";jmp M-I
164: wrt 715.9,"EBAT     VDC";jmp M-I
165: wrt 715.9,"EARM     VDC";jmp M-I
166: wrt 715.9,"EFM      VDC";jmp M-I
167: wrt 715.9,"IBAT     ADC";jmp M-I
168: wrt 715.9,"IBAT    ARMS";jmp M-I
169: wrt 715.9,"MOTR TEMP C";jmp M-I
170: wrt 715.9,"PTR       HP";jmp M-I
171: wrt 715.9,"PTR        W";jmp M-I
172: wrt 715.9,"PAMOT      W";jmp M-I
173: wrt 715.9,"MOTOR EFF %";jmp M-I
174: wrt 715.9,"WLMOT  W/Nm";jmp M-I
175: for P=1 to H
176: wrt 715.6,abs(B[I,P])
177: next P
178: wrt 715," "
179: next I
180: wtb 715,12
181: "raw data":
182: dsp "PRINT RAW DATA?";stp
183: wrt 715,"EVA DC MOTOR TEST RAW DATA"
184: fmt 3,c14,f3.0;wrt 715.3,"DATA ON FILE: ",G-2
185: gsb "clockprint"
186: wrt 715.5;fmt 4,f2.0,z;fmt 6,x,f9.4,z
187: fmt 9,2x,c11,z
188: 12→M
189: for I=1 to M-1
190: wrt 715.4,I
191: jmp I
192: wrt 715.9,"SPD SIG PER";jmp M-I
193: wrt 715.9,"TMOT     VDC";jmp M-I
194: wrt 715.9,"EBAT     VDC";jmp M-I
195: wrt 715.9,"EARM     VDC";jmp M-I
196: wrt 715.9,"EFM      VDC";jmp M-I
197: wrt 715.9,"IARM     VDC";jmp M-I
198: wrt 715.9,"TEMP MT VDC";jmp M-I
199: wrt 715.9,"EBAT    VRMS";jmp M-I
200: wrt 715.9,"EARM    VRMS";jmp M-I
201: wrt 715.9,"EFM     VRMS";jmp M-I
202: wrt 715.9,"IARM    VRMS";jmp M-I
203: for P=1 to H
204: wrt 715.6,A[I,P]
205: next P
206: wrt 715," "
207: next I
208: wtb 715,12
209: gto "data"
210: end
*6831
```

EVA DC MOTOR TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-05-23 11:21:30 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	MOTOR ROTOR SPEED
2	TMOT	FT-#	MOTOR SHAFT TORQUE
3	TMOT	Nm	MOTOR SHAFT TORQUE
4	EBAT	VDC	BATTERY VOLTAGE, AVERAGE VALUE
5	EARM	VDC	MOTOR ARMATURE VOLTAGE, AVERAGE VALUE
6	EFM	VDC	MOTOR SERIES FIELD VOLTAGE, AVERAGE VALUE
7	IBAT	ADC	BATTERY CURRENT, AVERAGE VALUE
8	IBAT	ARMS	BATTERY CURRENT, R.M.S. VALUE
9	MOTR	TEMP C	MOTOR TEMPERATURE, SERIES FIELD WINDING
10	PTR	HP	MOTOR POWER DELIVERED AT SHAFT
11	PTR	W	MOTOR POWER DELIVERED AT SHAFT
12	PAMOT	W	AVERAGE POWER CONSUMPTION OF MOTOR
13	MOTOR	EFF %	MOTOR EFFICIENCY
14	WLMOT	W/Nm	MOTOR WATT-LOSS/TORQUE DELIVERED AT SHAFT

Table C1: Nomenclature for DC Motor Test.

EVA DC MOTOR TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 1121; S.N.: 1276

79-06-22 17:30:07 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	663.821	838.567	1043.899	1304.886	1635.565	2045.377	2556.114	3201.353	3993.631
2	TMOT	FT-#	4.451	4.384	4.351	4.458	4.544	4.308	4.473	4.425	4.414
3	TMOT	Nm	6.035	5.944	5.899	6.045	6.161	5.841	6.065	5.999	5.985
4	EBAT	VDC	13.947	16.625	19.983	24.291	29.535	36.197	44.615	55.341	68.894
5	EARM	VDC	13.407	16.097	19.438	23.748	28.996	35.659	44.068	54.794	68.336
6	EFM	VDC	0.541	0.528	0.545	0.543	0.539	0.538	0.548	0.547	0.558
7	IBAT	ADC	52.306	51.829	52.048	52.473	52.377	52.166	52.443	52.762	53.616
8	IBAT	ARMS	52.296	51.975	51.895	52.337	52.377	52.216	52.437	52.918	53.741
9	MOTR	TEMP C	30.945	31.164	30.581	30.751	30.945	31.382	31.940	32.570	33.175
10	PTR	HP	0.563	0.700	0.865	1.108	1.415	1.678	2.177	2.697	3.356
11	PTR	W	419.562	522.031	644.915	826.022	1055.261	1251.040	1623.490	2011.263	2502.920
12	PAMOT	W	729.539	861.673	1040.048	1274.605	1546.945	1888.249	2339.754	2919.897	3693.841
13	MOTOR	EFF %	57.511	60.583	62.008	64.806	68.216	66.254	69.387	68.881	67.759
14	WLMOT	W/Nm	51.360	57.136	66.980	74.211	79.806	109.101	118.099	151.460	198.998

EVA DC MOTOR TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112D; S.N.: 1276

79-06-22 17:37:47 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	667.291	839.444	1048.254	1311.516	1639.266	2048.360	2559.452	3199.421	3996.465
2	TMOT	FT-#	8.843	8.835	8.812	8.687	8.759	8.882	8.754	8.802	8.726
3	TMOT	Nm	11.989	11.978	11.947	11.778	11.876	12.043	11.868	11.934	11.831
4	EBAT	VDC	16.427	19.656	23.703	28.627	34.933	42.808	52.654	65.209	80.732
5	EARM	VDC	15.646	18.882	22.920	27.857	34.151	42.020	51.870	64.416	79.938
6	EFM	VDC	0.781	0.775	0.783	0.770	0.782	0.788	0.784	0.793	0.795
7	IBAT	ADC	74.649	74.970	74.960	73.913	74.393	74.810	74.964	75.819	76.266
8	IBAT	ARMS	73.881	74.724	75.145	73.640	74.423	74.944	74.844	76.047	76.429
9	MOTR	TEMP C	31.455	31.188	31.625	32.328	33.175	33.416	34.213	35.081	36.140
10	PTR	HP	1.124	1.412	1.759	2.169	2.734	3.464	4.266	5.362	6.640
11	PTR	W	837.818	1053.001	1311.485	1617.610	2038.747	2583.257	3181.118	3998.522	4951.657
12	PAMOT	W	1226.234	1473.637	1776.774	2115.873	2598.731	3202.479	3947.174	4944.082	6157.139
13	MOTOR	EFF %	68.324	71.456	73.813	76.451	78.452	80.664	80.592	80.875	80.421
14	WLMOT	W/Nm	32.397	35.117	38.947	42.306	47.153	51.420	64.546	79.233	101.890

EVA DC MOTOR TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112D; S.N.: 1276

79-06-22 17:41:54 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	671.072	838.409	1048.486	1307.744	1639.998	2047.888	2560.464	3195.261	3996.176
2	TMOT	FT-#	12.938	13.142	13.319	13.085	13.176	13.046	13.257	13.275	13.060
3	TMOT	Nm	17.541	17.818	18.058	17.741	17.864	17.687	17.974	17.999	17.706
4	EBAT	VDC	18.179	21.678	26.058	31.315	38.282	46.778	57.683	71.007	87.779
5	EARM	VDC	17.159	20.649	25.009	30.273	37.234	45.726	56.614	69.933	86.706
6	EFM	VDC	1.020	1.029	1.049	1.042	1.047	1.052	1.069	1.074	1.073
7	IBAT	ADC	98.414	99.542	100.416	99.022	99.604	99.461	100.491	101.042	100.623
8	IEAT	ARMS	98.013	99.297	100.982	99.076	99.417	99.377	100.761	101.122	100.942
9	MOTR.TEMP	C	29.754	31.067	32.013	32.884	33.634	34.454	35.177	36.043	37.172
10	PTR	HP	1.653	2.098	2.659	3.258	4.114	5.087	6.463	8.077	9.937
11	PTR	W	1232.735	1564.429	1982.734	2429.602	3068.129	3793.223	4819.596	6022.648	7409.904
12	PAMOT	W	1789.094	2157.896	2616.649	3100.850	3812.987	4652.570	5796.588	7174.685	8832.543
13	MOTOR EFF	%	68.903	72.498	75.774	78.353	80.465	81.530	83.145	83.943	83.893
14	WLMOT	W/Nm	31.717	33.307	35.105	37.837	41.695	48.586	54.355	64.007	80.347

'EVA DC MOTOR TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPIO: 29 1755 112D; S.N.: 1276

79-06-22 17:40:46 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	200.779	646.315	818.605	1041.572	1304.209	1630.484	2051.718	2559.726	3202.894	3993.585
2	IMOT	FT-#	18.230	17.613	17.790	17.858	17.490	17.645	18.202	17.627	17.843	17.593
3	TMOT	Nm	24.716	23.880	24.120	24.211	23.713	23.923	24.678	23.899	24.192	23.853
4	EBAT	VDC	9.605	19.070	22.797	27.688	33.252	40.497	49.978	60.930	75.296	92.658
5	EARM	VDC	8.279	17.761	21.475	26.356	31.932	39.165	48.620	59.584	73.929	91.297
6	EFM	VDC	1.326	1.308	1.321	1.332	1.320	1.332	1.358	1.346	1.367	1.362
7	IBAT	ADC	125.541	122.819	123.194	123.955	121.995	122.623	124.807	123.004	124.308	123.834
8	IBAT	ARMS	125.114	122.787	123.068	120.460	122.185	122.787	124.793	123.269	124.492	124.232
9	MOTR TEMP	C	34.768	35.947	36.788	37.819	38.585	39.371	40.301	41.623	43.033	44.334
10	PTR	HP	0.697	2.167	2.773	3.542	4.343	5.478	7.111	8.591	10.882	13.378
11	PTR	W	519.677	1616.270	2067.696	2640.901	3238.707	4084.854	5302.475	6406.375	8114.371	9975.936
12	PAMOT	W	1205.826	2342.141	2808.403	3432.072	4056.586	4965.891	6237.644•	7494.640	9359.918	11474.297
13	MOTOR EFF	%	43.097	69.008	73.625	76.948	79.838	82.258	85.008	85.479	86.693	86.942
14	WLMCT	W/Nm	27.762	30.397	30.710	32.678	34.491	36.828	37.894	45.536	51.486	62.816

'EVA DC MOTOR TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 112D; S.N.: 1276

79-06-22 17:47:45 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	190.724	645.445	837.369	1033.921	1310.424	1640.440	2049.405	2557.972	3197.245	4002.018
2	TMOT	FT-#	22.312	22.228	22.176	22.064	21.852	22.070	22.230	21.856	21.850	22.041
3	TMOT	Nm	30.251	30.136	30.067	29.915	29.627	29.922	30.140	29.633	29.624	29.883
4	EBAT	VDC	10.215	20.228	24.546	28.896	35.108	42.709	52.090	63.532	78.303	97.027
5	EARM	VDC	8.630	18.636	22.954	27.318	33.528	41.106	50.473	61.923	76.682	95.391
6	EFM	VDC	1.584	1.592	1.592	1.577	1.580	1.603	1.616	1.609	1.621	1.636
7	IBAT	ADC	146.857	145.062	145.232	143.563	143.321	144.476	144.839	143.341	143.654	145.000
8	IBAT	ARMS	146.980	144.913	144.954	143.991	143.309	144.572	144.753	143.289	143.910	145.616
9	MOTR	TEMP C	38.824	40.943	42.060	43.340	44.948	46.432	48.194	49.622	51.209	52.512
10	PTR	HP	0.810	2.732	3.536	4.344	5.452	6.893	8.675	10.645	13.302	16.795
11	PTR	W	604.202	2037.002	2636.606	3239.030	4065.727	5140.353	6468.603	7938.041	9918.993	12523.976
12	PAMOT	W	1500.088	2934.268	3564.932	4148.351	5031.731	6170.431	7544.631	9106.724	11248.542	14068.857
13	MOTOR	EFF %	40.278	69.421	73.959	78.080	80.802	83.306	85.738	87.167	88.180	89.019
14	WLMOT	W/Nm	29.616	29.774	30.876	30.397	32.606	34.426	35.701	39.439	44.880	51.698

EVA DC MOTOR TEST WITH DC POWER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112D; S.N.: 1276

79-06-22   17:50:54   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	198.318	665.022	837.464	1049.912	1304.522	1639.574	2040.573	2561.240	3199.559
2	TMOT	FT-#	28.212	28.142	27.611	27.598	27.465	27.773	27.924	27.536	27.781
3	TMOT	Nm	38.250	38.155	37.435	37.418	37.237	37.654	37.859	37.334	37.666
4	EBAT	VDC	11.391	22.274	26.136	31.045	37.000	45.038	54.606	66.835	82.342
5	EARM	VDC	9.457	20.336	24.199	29.095	35.027	43.054	52.603	64.830	80.322
6	EFM	VDC	1.934	1.938	1.937	1.950	1.973	1.985	2.003	2.005	2.020
7	IBAT	ADC	174.131	173.455	170.568	170.065	170.063	170.943	171.399	169.902	171.244
8	IBAT	ARMS	172.697	173.800	170.550	170.450	170.530	171.252	171.854	170.229	171.994
9	MOTR	TEMP C	44.900	46.667	49.715	51.605	54.044	55.802	56.979	58.635	60.195
10	PTR	HP	1.065	3.563	4.403	5.517	6.822	8.670	10.849	13.429	16.925
11	PTR	W	794.394	2657.256	3283.084	4114.112	5087.129	6465.284	8090.374	10013.752	12620.625
12	PAMOT	W	1983.455	3863.532	4457.902	5279.624	6292.233	7698.961	9359.344	11355.378	14100.555
13	MOTOR	EFF %	40.051	68.778	73.646	77.924	80.848	83.976	86.442	88.185	89.504
14	WLMOT	W/Nm	31.087	31.615	31.383	31.149	32.363	32.763	33.518	35.936	39.291

APPENDIX D1

PARAMETRIC TEST DATA, UNBUFFERED BATTERY MOTOR CHOPPER ENGINEERING DATA AND CALCULATED DATA FOR PULSED DC POWER OPERATION

(UN)
EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-05-23 11:28:23 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	MOTOR ROTOR SPEED
2	TMOT	FT-#	MOTOR SHAFT TORQUE
3	EBAT	VDC	BATTERY TERMINAL VOLTAGE, AVERAGE VALUE
4	EARM	VDC	MOTOR ARMATURE VOLTAGE, AVERAGE VALUE
5	EFM	VDC	MOTOR FIELD VOLTAGE, AVERAGE VALUE
6	IBAT′	ADC	BATTERY CURRENT, AVERAGE VALUE
7	IARM	ADC	MOTOR CURRENT, AVERAGE VALUE
8	ITH1	ADC	CURRENT IN THYRISTOR TH1(x), AVERAGE VALUE
9	ID2	ADC	CURRENT IN INVERSE BY-PASS DIODE D2(x), AVERAGE VALUE
10	VCT1	VDC	VOLTAGE DROP ACROSS CONTACTOR, AVERAGE VALUE
11	ETH1	VDC	VOLTAGE FROP DURING ON-CYCLE OF TH1(x), AVERAGE VALUE
12	EDF2	VDC	VOLTAGE DROP DURING ON-CYCLE OF D2(x), AVERAGE VALUE
15	PLAC4	W	POWER LOSS WITHIN COMMUTATING CAPACITOR C4, AVERAGE VALUE
16	MOTR TEMP	C	MOTOR FIELD WINDING TEMPERATURE
17	CONTROLR	HZ	DC CHOPPER PULSE REPETITION FREQUENCY
18	EBAT	VRMS	BATTERY TERMINAL VOLTAGE, R.M.S. VALUE
19	EARM	VRMS	MOTOR ARMATURE VOLTAGE, R.M.S. VALUE
20	EFM	VRMS	MOTOR FIELD VOLTAGE, R.M.S. VALUE
21	IBAT′	ARMS	BATTERY CURRENT, R.M.S. VALUE
22	IARM	ARMS	MOTOR CURRENT, R.M.S. VALUE
23	ITH1	ARMS	CURRENT IN THYRISTOR TH1, R.M.S. VALUE
24	ID2	ARMS	CURRENT IN INVERSE BY-PASS DIODE D2, R.M.S. VALUE
25	IC4	ARMS	CURRENT IN CAPACITOR C4, R.M.S. VALUE
26	ITH2	ARMS	CURRENT IN THYRISTOR TH2, R.M.S. VALUE
27	ID4	ARMS	CURRENT IN DIODE D4, R.M.S. VALUE
28	VCT1	VRMS	VOLTAGE DROP ACROSS CONTACTOR CT1, R.M.S. VALUE
29	ETH1	VRMS	VOLTAGE DROP DURING ON-CYCLE OF TH1(x), R.M.S. VALUE
30	EDF2	VRMS	VOLTAGE DROP DURING ON-CYCLE OF D2(x), R.M.S. VALUE
31	VC4	VRMS	CAPACITOR C4 VOLTAGE (x) DURING COMMUTATION, R.M.S. VALUE
34	PLC4	W	HEAT LOSS IN CAPACITOR C4
35	VINT	VRMS	VOLTAGE DROP ACROSS TH2 CURRENT SHUNT, R.M.S. VALUE
36	VINT	VDC	VOLTAGE DROP ACROSS TH2 CURRENT SHUNT, AVERAGE VALUE

(x) THIS DATA OBTAINED FROM EXTERNAL ADAPTOR CIRCUIT

Table D1. Nomenclature for Parametric Test Data (Un)buffered Battery.

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112B; S.N.: 1276

79-06-22 16:01:06 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	83.739	51.939	52.176	46.255	53.394	55.314
2	TMOT	FT-#	4.655	8.631	13.443	17.173	21.779	27.140
3	EBAT	VDC	103.194	100.917	98.427	96.530	95.086	93.819
4	EARM	VDC	1.652	2.331	3.030	3.530	3.996	4.713
5	EFM	VDC	0.172	1.098	0.827	1.253	1.670	1.881
6	IBAT	ADC	4.211	6.602	9.998	13.715	18.453	24.576
7	IARM	ADC	43.898	71.196	98.644	115.743	142.371	169.735
8	ITH1	ADC	4.198	5.825	9.269	13.230	16.554	22.752
9	ID2	ADC	41.917	62.823	86.904	105.425	122.306	146.692
10	VCT1	VDC	0.050	0.073	0.096	0.114	0.137	0.163
11	ETH1	VDC	0.062	0.073	0.098	0.116	0.141	0.156
12	EDF2	VDC	0.678	0.670	0.667	0.658	0.649	0.644
~~13~~	~~PLABT~~	~~W~~	~~21.060~~	~~47.127~~	~~79.422~~	~~179.017~~	~~464.838~~	~~854.392~~
~~14~~	~~PLACOM~~	~~W~~	~~32.835~~	~~47.906~~	~~64.747~~	~~73.586~~	~~79.595~~	~~95.158~~
15	PLAC4	W	4.554	4.776	4.996	5.243	5.472	5.785
16	MOTR TEMP	C	26.235	27.361	29.144	31.334	33.972	38.848
17	CONTROLR	HZ	33.541	47.775	104.370	148.336	173.496	205.636
18	EBAT	VRMS	102.992	100.697	98.297	96.407	95.089	93.896
19	EARM	VRMS	2.539	3.222	3.985	4.776	5.529	6.418
20	EFM	VRMS	15.629	17.058	18.292	18.598	18.872	19.460
21	IBAT	ARMS	23.550	33.721	45.175	55.105	66.639	82.427
22	IARM	ARMS	57.112	85.492	113.813	137.115	160.866	191.160
23	ITH1	ARMS	24.062	34.778	45.960	56.272	67.980	83.832
24	ID2	ARMS	52.968	79.996	106.782	128.312	149.680	174.292
25	IC4	ARMS	15.205	19.238	24.714	28.044	32.016	37.332
26	ITH2	ARMS	13.212	18.212	22.784	26.196	29.620	33.420
27	ID4	ARMS	5.968	8.120	9.616	10.164	9.884	8.284
28	VCT1	VRMS	0.061	0.089	0.115	0.139	0.161	0.193
29	ETH1	VRMS	0.303	0.352	0.393	0.428	0.463	0.506
30	EDF2	VRMS	0.687	0.689	0.688	0.686	0.684	0.681
31	VC4	VRMS	27.342	30.310	33.226	35.801	38.803	42.890
~~32~~	~~PLBT~~	~~W~~	~~128.928~~	~~170.159~~	~~250.358~~	~~408.451~~	~~639.066~~	~~987.506~~
~~33~~	~~PLCOM~~	~~W~~	~~777.076~~	~~1003.156~~	~~1151.171~~	~~1259.441~~	~~1343.155~~	~~1426.683~~
34	PLC4	W	16.351	20.785	25.226	28.923	32.879	37.712
35	VINT	VRMS	0.016	0.023	0.031	0.038	0.046	0.056
36	VINT	VDC	0.002	0.004	0.006	0.009	0.011	0.016

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112U; S.N.: 1276

79-06-22 16:05:14 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	202.308	199.172	197.473	203.871	196.461	201.611
2	TMOT	FT-#	4.833	8.651	12.834	17.103	22.710	27.457
3	EBAT	VDC	99.208	97.534	95.776	94.493	93.560	92.766
4	EARM	VDC	3.774	4.873	5.728	6.604	7.376	8.218
5	EFM	VDC	0.002	0.592	0.746	1.469	1.665	1.850
6	IBAT′	ADC	6.796	9.896	14.455	19.867	26.461	33.867
7	IARM	ADC	49.578	71.429	95.547	117.075	147.613	171.337
8	ITH1	ADC	6.323	10.270	14.542	18.004	26.120	33.470
9	ID2	ADC	42.709	63.397	82.719	99.633	121.358	139.894
10	VCT1	VDC	0.042	0.066	0.088	0.108	0.138	0.163
11	ETH1	VDC	0.083	0.104	0.129	0.165	0.185	0.224
12	EDF2	VDC	0.649	0.643	0.637	0.622	0.615	0.604
~~13~~	~~PLABT~~	~~W~~	~~22.522~~	~~52.412~~	~~83.399~~	~~192.535~~	~~630.004~~	~~1024.356~~
~~14~~	~~PLACOM~~	~~W~~	~~32.468~~	~~73.353~~	~~86.167~~	~~94.490~~	~~108.460~~	~~120.209~~
15	PLAC4	W	4.661	4.875	5.150	5.496	5.909	6.317
16	MOTR TEMP	C	30.556	31.212	32.836	34.503	37.244	40.801
17	CONTROLR	HZ	57.897	76.582	138.841	217.885	250.943	283.183
18	EBAT	VRMS	99.011	97.430	95.688	94.508	93.623	92.893
19	EARM	VRMS	4.493	5.537	6.576	7.576	8.626	9.721
20	EFM	VRMS	19.203	21.217	21.990	22.460	22.651	22.875
21	IBAT′	ARMS	30.531	40.421	52.337	64.694	80.541	96.228
22	IARM	ARMS	60.627	88.285	114.516	139.888	169.792	194.832
23	ITH1	ARMS	30.472	41.107	53.320	64.987	82.073	97.663
24	ID2	ARMS	55.022	79.775	104.164	125.895	151.453	173.184
25	IC4	ARMS	18.977	24.373	29.348	33.179	38.736	43.550
26	ITH2	ARMS	16.664	21.588	25.992	29.708	33.908	37.836
27	ID4	ARMS	7.204	8.620	9.292	8.648	7.056	6.272
28	VCT1	VRMS	0.058	0.083	0.108	0.134	0.165	0.192
29	ETH1	VRMS	0.411	0.458	0.492	0.526	0.565	0.612
30	EDF2	VRMS	0.667	0.670	0.670	0.668	0.666	0.663
31	VC4	VRMS	31.759	35.745	39.217	42.876	48.192	53.954
~~32~~	~~PLBT~~	~~W~~	~~182.708~~	~~206.971~~	~~299.764~~	~~488.479~~	~~831.387~~	~~1188.406~~
~~33~~	~~PLCOM~~	~~W~~	~~1005.353~~	~~1196.822~~	~~1350.354~~	~~1478.878~~	~~1611.858~~	~~1674.804~~
34	PLC4	W	20.167	25.043	29.768	34.297	39.406	44.237
35	VINT	VRMS	0.020	0.028	0.036	0.045	0.056	0.066
36	VINT	VDC	0.005	0.007	0.009	0.012	0.017	0.022

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22 16:09:29 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	667.682	667.357	667.609	668.428	671.419	665.263
2	TMOT	FT-#	4.496	8.626	13.279	19.269	22.337	27.840
3	EBAT	VDC	96.738	94.589	93.551	92.474	91.993	91.203
4	EARM	VDC	10.502	13.032	14.899	16.686	17.472	18.565
5	EFM	VDC	0.006	0.812	0.985	1.435	1.361	1.735
6	IBAT′	ADC	13.577	19.883	28.074	39.663	46.090	59.771
7	IARM	ADC	49.223	73.651	99.615	128.741	146.279	173.973
8	ITH1	ADC	12.771	19.340	27.677	39.997	46.017	58.555
9	ID2	ADC	37.547	54.487	71.962	90.010	100.025	116.639
10	VCT1	VDC	0.051	0.075	0.100	0.129	0.151	0.180
11	ETH1	VDC	0.148	0.206	0.258	0.316	0.352	0.389
12	EDF2	VDC	0.581	0.565	0.551	0.531	0.520	0.507
13	~~PLABT~~	~~W~~	~~8.521~~	~~68.097~~	~~112.600~~	~~273.411~~	~~795.739~~	~~1277.900~~
14	~~PLACOM~~	~~W~~	~~83.577~~	~~114.712~~	~~143.907~~	~~161.228~~	~~168.167~~	~~182.516~~
15	PLAC4	W	4.625	5.551	11.053	4.261	3.708	1.985
16	MOTR TEMP	C	33.634	34.551	35.683	38.895	41.585	45.231
17	CONTROLR	HZ	125.202	156.865	180.263	403.546	424.707	452.859
18	EBAT	VRMS	96.534	94.549	93.570	92.566	92.152	91.445
19	EARM	VRMS	11.073	13.638	15.618	17.330	18.524	19.822
20	EFM	VRMS	28.596	29.968	30.331	30.249	30.084	29.614
21	IBAT′	ARMS	40.762	55.145	72.276	90.912	105.756	124.914
22	IARM	ARMS	69.260	93.812	122.173	151.842	172.175	199.734
23	ITH1	ARMS	43.190	57.142	72.994	92.345	106.661	126.254
24	ID2	ARMS	58.728	81.023	103.963	130.266	141.725	161.483
25	IC4	ARMS	27.362	34.202	40.682	47.281	50.712	56.288
26	ITH2	ARMS	22.752	28.072	33.520	40.320	42.632	47.384
27	ID4	ARMS	8.148	7.472	6.820	7.340	7.876	8.776
28	VCT1	VRMS	0.073	0.100	0.129	0.161	0.184	0.214
29	ETH1	VRMS	0.665	0.697	0.733	0.780	0.812	0.860
30	EDF2	VRMS	0.630	0.628	0.625	0.619	0.615	0.611
31	VC4	VRMS	45.458	52.338	59.679	67.328	72.414	79.148
32	~~PLBT~~	~~W~~	~~340.441~~	~~292.802~~	~~425.878~~	~~826.248~~	~~1039.415~~	~~1476.151~~
33	~~PLCOM~~	~~W~~	~~1457.797~~	~~1677.203~~	~~1875.746~~	~~2037.878~~	~~2119.692~~	~~2171.419~~
34	PLC4	W	27.950	24.198	70.722	88.199	94.475	104.802
35	VINT	VRMS	0.028	0.038	0.050	0.066	0.073	0.086
36	VINT	VDC	0.008	0.013	0.019	0.025	0.031	0.039

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112B; S.N.: 1276

79-06-22 16:13:26 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	838.306	835.994	839.080	839.840	831.771	839.557
2	TMOT	FT-#	4.531	9.443	13.206	17.552	21.933	26.474
3	EBAT	VDC	96.342	94.358	93.370	92.531	91.779	90.915
4	EARM	VDC	13.100	16.574	18.314	19.809	21.022	22.307
5	EFM	VDC	0.841	0.960	1.237	1.004	1.430	1.906
6	IBAT′	ADC	15.679	24.999	32.295	42.730	52.976	64.553
7	IARM	ADC	49.588	77.851	98.791	122.595	143.900	165.922
8	ITH1	ADC	14.459	24.436	33.264	41.366	52.910	64.186
9	ID2	ADC	34.870	54.299	66.841	80.691	91.981	102.907
10	VCT1	VDC	0.049	0.076	0.096	0.119	0.140	0.162
11	ETH1	VDC	0.175	0.254	0.298	0.340	0.388	0.437
12	EDF2	VDC	0.552	0.534	0.520	0.502	0.487	0.472
13	~~PLABT~~	~~W~~	~~1.331~~	~~83.753~~	~~124.954~~	~~220.397~~	~~781.293~~	~~1180.316~~
14	~~PLACOM~~	~~W~~	~~95.148~~	~~133.029~~	~~153.386~~	~~170.475~~	~~184.926~~	~~200.383~~
15	PLAC4	W	4.630	12.196	5.324	4.177	2.862	1.599
16	MOTR TEMP	C	36.764	37.459	38.943	41.253	43.435	47.114
17	CONTROLR	HZ	146.859	186.070	204.477	441.327	466.893	492.029
18	EBAT	VRMS	96.129	94.317	93.478	92.708	91.957	91.132
19	EARM	VRMS	13.649	17.212	19.027	20.690	21.977	23.446
20	EFM	VRMS	30.925	32.371	32.676	32.374	31.812	31.377
21	IBAT′	ARMS	44.714	62.828	77.712	93.299	110.149	128.785
22	IARM	ARMS	70.843	101.020	123.540	147.017	170.456	193.015
23	ITH1	ARMS	46.648	64.300	78.130	94.994	111.412	129.812
24	ID2	ARMS	58.346	84.6[illegible]9	101.344	118.665	135.139	150.506
25	IC4	ARMS	29.508	38.575	43.631	48.625	52.958	57.612
26	ITH2	ARMS	24.108	30.908	35.292	39.828	44.064	48.320
27	ID4	ARMS	8.000	7.048	7.216	7.764	8.568	9.516
28	VCT1	VRMS	0.072	0.104	0.128	0.150	0.174	0.199
29	ETH1	VRMS	0.730	0.771	0.797	0.836	0.874	0.918
30	EDF2	VRMS	0.613	0.612	0.607	0.601	0.597	0.590
31	VC4	VRMS	49.918	59.908	66.200	72.396	78.313	84.270
32	~~PLBT~~	~~W~~	~~375.752~~	~~361.640~~	~~445.999~~	~~678.728~~	~~1022.215~~	~~1404.432~~
33	~~PLCOM~~	~~W~~	~~1576.911~~	~~1851.316~~	~~2004.722~~	~~2117.650~~	~~2219.283~~	~~2299.803~~
34	PLC4	W	29.945	67.782	80.204	90.253	99.269	107.607
35	VINT	VRMS	0.031	0.043	0.053	0.065	0.076	0.088
36	VINT	VDC	0.010	0.016	0.021	0.027	0.034	0.042

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121J; S.N.: 1276

79-06-22   16:17:24   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1048.524	1046.037	1048.154	1046.017	1044.684	1044.216
2	TMOT	FT-#	4.586	9.883	12.864	17.480	21.830	28.115
3	EBAT	VDC	95.423	93.743	92.970	92.004	91.103	89.875
4	EARM	VDC	16.485	20.590	22.323	24.195	25.720	27.409
5	EFM	VDC	0.502	1.068	1.330	1.445	1.325	1.915
6	IBAT′	ADC	18.275	28.283	37.673	49.261	61.490	78.294
7	IARM	ADC	51.727	81.425	97.320	122.829	144.162	173.141
8	ITH1	ADC	18.081	28.342	36.629	49.450	61.008	78.561
9	ID2	ADC	33.690	51.863	60.170	74.089	84.064	94.964
10	VCT1	VDC	0.048	0.077	0.094	0.118	0.142	0.171
11	ETH1	VDC	0.215	0.295	0.349	0.406	0.452	0.524
12	EDF2	VDC	0.485	0.498	0.481	0.466	0.442	0.425
13	~~PLABT~~	~~W~~	~~3.236~~	~~90.081~~	~~135.218~~	~~215.242~~	~~785.933~~	~~1302~~.710
14	~~PLACOM~~	~~W~~	~~104.186~~	~~145.348~~	~~164.402~~	~~186.479~~	~~200.873~~	~~218.~~047
15	PLAC4	W	11.441	5.674	4.431	3.241	1.596	0.278
16	MOTR TEMP	C	37.675	38.704	40.753	43.269	45.655	49.130
17	CONTROLR	HZ	172.811	213.947	229.418	366.595	514.754	539.012
18	EBAT	VRMS	95.262	93.770	93.077	92.169	91.315	90.169
19	EARM	VRMS	17.076	21.290	23.055	25.054	26.609	28.471
20	EFM	VRMS	33.358	34.803	34.815	34.196	33.576	32.571
21	IBAT′	ARMS	48.866	68.685	81.805	100.581	118.394	143.108
22	IARM	ARMS	73.421	104.047	122.446	148.053	170.749	199.851
23	ITH1	ARMS	50.267	70.628	83.266	101.909	119.642	144.371
24	ID2	ARMS	59.030	83.359	96.994	114.999	129.037	146.639
25	IC4	ARMS	32.537	41.243	45.717	51.173	55.586	61.183
26	ITH2	ARMS	25.468	33.020	36.900	41.884	46.104	51.256
27	ID4	ARMS	7.540	7.272	7.840	8.756	9.636	10.896
28	VCT1	VRMS	0.074	0.105	0.125	0.152	0.176	0.206
29	ETH1	VRMS	0.791	0.850	0.872	0.911	0.952	1.011
30	EDF2	VRMS	0.594	0.591	0.586	0.579	0.573	0.563
31	VC4	VRMS	55.278	67.224	72.496	79.403	85.300	92.596
32	~~PLBT~~	~~W~~	~~436.301~~	~~385.760~~	~~458.805~~	~~691.472~~	~~1033.053~~	~~1532.~~204
33	~~PLCOM~~	~~W~~	~~1700.839~~	~~1990.045~~	~~2117.354~~	~~2233.492~~	~~2319.559~~	~~2910.~~297
34	PLC4	W	55.804	76.636	84.482	94.644	103.415	113.544
35	VINT	VRMS	0.034	0.048	0.056	0.069	0.082	0.097
36	VINT	VDC	0.012	0.020	0.025	0.033	0.040	0.052

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112B; S.N.: 1276

79-06-22 16:21:26 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1310.714	1306.036	1305.814	1303.291	1303.788	1301.771
2	TMOT	FT-#	4.775	8.711	12.863	18.194	21.704	28.207
3	EBAT	VDC	94.700	93.390	92.398	91.199	90.321	88.784
4	EARM	VDC	20.510	24.703	27.425	29.970	31.464	33.645
5	EFM	VDC	0.678	1.104	0.987	1.287	1.556	1.928
6	IBAT´	ADC	21.881	32.339	43.283	59.458	70.531	92.467
7	IARM	ADC	50.148	74.638	97.125	124.300	141.933	173.442
8	ITH1	ADC	21.205	31.935	43.380	59.509	71.106	93.109
9	ID2	ADC	29.509	42.971	53.232	64.051	71.467	80.463
10	VCT1	VDC	0.053	0.079	0.103	0.129	0.148	0.177
11	ETH1	VDC	0.250	0.337	0.414	0.484	0.536	0.621
12	EDF2	VDC	0.415	0.452	0.439	0.413	0.395	0.368
13	PLABT	W	~~44.854~~	~~69.104~~	~~135.857~~	~~218.717~~	~~301.310~~	~~1286.371~~
14	PLACOM	W	~~96.427~~	~~142.311~~	~~175.525~~	~~201.538~~	~~212.782~~	~~226.166~~
15	PLAC4	W	8.035	5.488	4.008	2.191	1.117	0.264
16	MOTR TEMP	C	40.753	41.965	43.317	45.537	48.733	52.907
17	CONTROLR	HZ	196.523	235.797	255.401	270.191	277.258	284.739
18	EBAT	VRMS	94.587	93.427	92.501	91.366	90.543	89.100
19	EARM	VRMS	21.044	25.405	28.197	30.757	32.273	34.495
20	EFM	VRMS	36.152	37.084	36.785	35.816	35.028	33.548
21	IBAT´	ARMS	50.652	69.307	87.462	109.788	125.495	152.998
22	IARM	ARMS	72.503	98.402	122.563	150.924	169.186	200.262
23	ITH1	ARMS	53.361	70.446	88.463	111.796	126.699	154.137
24	ID2	ARMS	56.956	74.981	92.322	109.421	119.793	135.864
25	IC4	ARMS	33.500	41.424	48.284	53.500	56.750	62.266
26	ITH2	ARMS	25.864	33.040	38.436	43.912	47.196	52.236
27	ID4	ARMS	7.484	7.716	8.604	9.888	10.732	12.076
28	VCT1	VRMS	0.081	0.111	0.138	0.166	0.183	0.213
29	ETH1	VRMS	0.887	0.923	0.961	1.001	1.034	1.093
30	EDF2	VRMS	0.566	0.566	0.558	0.548	0.539	0.527
31	VC4	VRMS	60.555	71.707	79.452	86.990	91.656	98.922
32	PLBT	W	~~700.859~~	~~397.800~~	~~473.186~~	~~711.821~~	~~982.926~~	~~1518.486~~
33	PLCOM	W	~~1788.838~~	~~2063.539~~	~~2218.395~~	~~2971.373~~	~~3027.930~~	~~3028.865~~
34	PLC4	W	61.969	77.636	88.813	98.708	104.909	114.060
35	VINT	VRMS	0.035	0.048	0.060	0.076	0.086	0.105
36	VINT	VDC	0.014	0.021	0.029	0.039	0.047	0.061

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112D; S.N.: 1276

79-06-22 16:26:16 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1638.459	1640.059	1638.571	1642.319	1636.567	1637.213
2	TMOT	FT-#	4.483	8.800	12.909	17.677	22.294	28.567
3	EBAT	VDC	93.979	92.621	91.581	90.306	89.091	87.297
4	EARM	VDC	25.403	31.051	34.281	37.110	39.153	41.664
5	EFM	VDC	0.790	0.728	1.080	1.245	1.624	1.951
6	IBAT´	ADC	24.160	38.910	52.521	68.625	87.084	110.912
7	IARM	ADC	50.439	75.685	97.705	120.928	144.754	174.278
8	ITH1	ADC	24.464	38.434	52.386	68.764	85.996	112.215
9	ID2	ADC	25.830	36.838	45.104	52.215	57.802	62.940
10	VCT1	VDC	0.046	0.070	0.091	0.114	0.137	0.169
11	ETH1	VDC	0.298	0.425	0.509	0.580	0.648	0.749
12	EDF2	VDC	0.353	0.381	0.375	0.349	0.322	0.293
13	PLABT	W	~~32.484~~	~~67.650~~	~~146.036~~	~~199.579~~	~~279.102~~	~~1201.568~~
14	PLACOM	W	~~104.698~~	~~152.160~~	~~181.903~~	~~203.244~~	~~213.516~~	~~221.106~~
15	PLAC4	W	7.702	4.993	3.336	1.974	0.745	0.200
16	MOTR TEMP	C	43.577	44.594	46.079	48.850	51.954	56.102
17	CONTROLR	HZ	220.235	262.468	277.681	285.730	287.852	284.900
18	EBAT	VRMS	93.951	92.708	91.678	90.476	89.256	87.579
19	EARM	VRMS	25.769	31.716	34.948	37.778	39.899	42.398
20	EFM	VRMS	37.701	38.999	38.288	37.039	35.605	33.657
21	IBAT´	ARMS	56.389	75.907	95.024	116.890	138.193	166.017
22	IARM	ARMS	73.069	99.965	123.345	148.365	171.706	201.004
23	ITH1	ARMS	58.072	77.281	96.207	118.388	140.084	168.230
24	ID2	ARMS	53.170	71.779	85.897	97.941	109.098	119.632
25	IC4	ARMS	34.182	43.229	50.090	54.322	57.853	62.005
26	ITH2	ARMS	27.224	34.508	39.780	44.192	47.876	51.548
27	ID4	ARMS	7.012	8.516	9.828	10.992	12.116	13.364
28	VCT1	VRMS	0.074	0.100	0.124	0.148	0.174	0.204
29	ETH1	VRMS	0.882	1.001	1.058	1.087	1.130	1.185
30	EDF2	VRMS	0.524	0.526	0.519	0.506	0.494	0.476
31	VC4	VRMS	63.830	78.292	86.262	92.677	97.664	102.800
32	PLBT	W	~~608.294~~	~~431.908~~	~~487.692~~	~~643.625~~	~~951.077~~	~~1422.087~~
33	PLCOM	W	~~1889.893~~	~~2168.786~~	~~2302.826~~	~~3040.862~~	~~3065.324~~	~~3063.143~~
34	PLC4	W	65.050	80.638	91.480	99.776	103.549	102.929
35	VINT	VRMS	0.039	0.052	0.065	0.080	0.094	0.113
36	VINT	VDC	0.016	0.026	0.035	0.045	0.057	0.074

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22 16:30:10 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	2049.558	2049.695	2048.924	2046.712	2049.481	2047.546
2	TMOT	FT-#	4.254	9.070	13.678	17.974	22.067	27.685
3	EBAT	VDC	93.837	91.770	90.383	88.984	87.557	85.706
4	EARM	VDC	31.152	38.865	43.085	45.901	48.200	50.971
5	EFM	VDC	0.507	1.192	1.217	1.749	1.551	1.967
6	IBAT´	ADC	28.281	47.177	65.390	84.354	101.953	130.071
7	IARM	ADC	49.572	78.112	101.828	123.442	142.851	170.741
8	ITH1	ADC	28.156	47.032	65.798	84.208	103.799	131.309
9	ID2	ADC	21.387	30.770	35.877	39.420	40.546	41.420
10	VCT1	VDC	0.055	0.085	0.109	0.128	0.146	0.171
11	ETH1	VDC	0.351	0.521	0.638	0.712	0.792	0.902
12	EDF2	VDC	0.261	0.291	0.287	0.264	0.247	0.208
13	PLABT	W	~~52.754~~	~~53.674~~	~~160.724~~	~~210.408~~	~~247.550~~	~~291.589~~
14	PLACOM	W	~~106.805~~	~~151.828~~	~~182.578~~	~~191.658~~	~~191.448~~	~~185.730~~
15	PLAC4	W	7.517	5.226	3.367	2.089	3.195	7.429
16	MOTR TEMP	C	45.608	46.902	48.709	51.838	54.600	58.291
17	CONTROLR	HZ	242.334	280.536	286.073	282.425	274.295	256.937
18	EBAT	VRMS	93.689	91.787	90.483	89.146	87.752	85.964
19	EARM	VRMS	31.986	39.598	43.722	46.534	48.866	51.554
20	EFM	VRMS	38.753	39.834	38.630	36.881	34.884	32.555
21	IBAT´	ARMS	59.478	84.212	106.779	127.943	147.622	174.803
22	IARM	ARMS	74.573	103.188	128.618	150.455	170.573	196.687
23	ITH1	ARMS	60.822	84.944	107.570	129.186	150.740	177.147
24	ID2	ARMS	49.706	66.442	78.284	86.884	92.302	95.202
25	IC4	ARMS	35.707	44.232	49.909	53.821	55.887	56.248
26	ITH2	ARMS	27.732	34.976	40.048	43.324	45.348	46.668
27	ID4	ARMS	7.156	9.212	10.964	12.124	13.048	13.872
28	VCT1	VRMS	0.086	0.119	0.145	0.163	0.181	0.201
29	ETH1	VRMS	0.936	1.034	1.135	1.163	1.213	1.278
30	EDF2	VRMS	0.468	0.470	0.461	0.449	0.433	0.407
31	VC4	VRMS	67.127	81.293	90.597	95.852	98.545	100.026
32	PLBT	W	~~763.501~~	~~471.653~~	~~482.449~~	~~596.026~~	~~767.770~~	~~1025.448~~
33	PLCOM	W	~~1969.791~~	~~2220.342~~	~~2312.532~~	~~2999.574~~	~~2318.204~~	~~2256.707~~
34	PLC4	W	66.191	80.848	89.434	90.417	51.600	55.097
35	VINT	VRMS	0.041	0.057	0.073	0.087	0.101	0.118
36	VINT	VDC	0.019	0.031	0.043	0.056	0.068	0.085

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121J; S.N.: 1276

79-06-22 16:36:15 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	2559.924	2560.091	2560.769	2560.056	2560.980	2559.902
2	TMOT	FT-#	4.398	8.871	13.255	17.416	21.777	27.355
3	EBAT	VDC	92.510	90.725	89.146	87.489	85.765	83.370
4	EARM	VDC	39.492	48.056	53.038	56.469	59.351	62.488
5	EFM	VDC	0.533	1.031	1.093	1.140	1.590	2.099
6	IBAT´	ADC	34.256	55.546	76.112	98.685	120.787	150.655
7	IARM	ADC	51.363	76.772	99.574	121.798	143.027	170.024
8	ITH1	ADC	34.050	54.820	76.179	99.709	121.929	153.158
9	ID2	ADC	17.314	21.358	23.439	22.682	21.358	17.693
10	VCT1	VDC	0.047	0.071	0.093	0.115	0.136	0.161
11	ETH1	VDC	0.429	0.615	0.753	0.869	0.972	1.108
12	EDF2	VDC	0.222	0.218	0.191	0.168	0.140	0.099
13	PLABT	W	~~88.896~~	~~28.597~~	~~77.357~~	~~157.891~~	~~203.665~~	~~151.937~~
14	PLACOM	W	~~91.265~~	~~127.351~~	~~142.548~~	~~141.218~~	~~128.300~~	~~103.480~~
15	PLAC4	W	7.711	5.677	9.703	5.721	6.103	5.756
16	MOTR TEMP	C	48.545	49.879	51.977	54.368	57.877	61.887
17	CONTROLR	HZ	278.233	377.098	293.440	247.786	217.682	174.742
18	EBAT	VRMS	92.512	90.812	89.229	87.658	85.889	83.508
19	EARM	VRMS	40.350	48.803	53.625	57.086	59.843	62.922
20	EFM	VRMS	40.067	39.980	37.573	34.957	32.150	27.582
21	IBAT´	ARMS	63.370	88.625	111.253	132.958	154.843	180.500
22	IARM	ARMS	74.319	101.215	124.907	145.806	166.276	189.128
23	ITH1	ARMS	64.785	89.130	113.030	134.847	157.312	183.375
24	ID2	ARMS	44.751	55.385	61.649	64.468	63.945	57.822
25	IC4	ARMS	35.426	40.842	44.533	45.556	45.396	40.963
26	ITH2	ARMS	27.568	32.848	35.904	37.084	36.968	33.712
27	ID4	ARMS	7.368	9.268	10.696	11.604	12.212	11.596
28	VCT1	VRMS	0.075	0.101	0.124	0.144	0.163	0.183
29	ETH1	VRMS	0.956	1.064	1.156	1.228	1.294	1.350
30	EDF2	VRMS	0.412	0.404	0.383	0.360	0.337	0.291
31	VC4	VRMS	69.656	80.955	85.852	88.218	89.278	85.577
32	PLBT	W	~~1061.463~~	~~673.941~~	~~465.581~~	~~431.577~~	~~435.286~~	~~367.214~~
33	PLCOM	W	~~2012.419~~	~~2177.277~~	~~2161.510~~	~~2099.857~~	~~2007.013~~	~~1778.586~~
34	PLC4	W	65.643	74.854	45.308	44.532	43.991	39.905
35	VINT	VRMS	0.044	0.060	0.076	0.090	0.104	0.121
36	VINT	VDC	0.023	0.037	0.050	0.064	0.080	0.101

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22 16:42:19 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	3199.838	3198.573	3201.180	3198.121	3196.525
2	TMOT	FT-#	4.521	8.746	13.475	17.728	26.413
3	EBAT	VDC	91.520	89.529	87.409	85.517	81.599
4	EARM	VDC	49.204	59.278	65.701	69.837	77.307
5	EFM	VDC	0.558	0.647	1.264	1.555	1.849
6	IBAT′	ADC	40.084	63.747	90.320	113.146	163.852
7	IARM	ADC	52.275	76.003	100.699	120.384	165.000
8	ITH1	ADC	39.407	64.219	91.184	115.529	165.935
9	ID2	ADC	12.034	12.475	9.865	6.817	0.105
10	VCT1	VDC	0.046	0.068	0.092	0.113	0.153
11	ETH1	VDC	0.526	0.741	0.920	1.053	1.324
12	EDF2	VDC	0.161	0.129	0.089	0.053	0.020
13	PLABT	W	124.304	186.479	146.675	166.056	$$$$$$$$$
14	PLACOM	W	~~64.148~~	~~75.091~~	~~69.276~~	~~51.826~~	~~1.750~~
15	PLAC4	W	~~8.370~~	~~3.481~~	~~4.784~~	~~4.878~~	~~4.876~~
16	MOTR TEMP	C	50.603	52.117	53.812	56.264	59.416
17	CONTROLR	HZ	516.227	406.659	301.391	191.445	1.000
18	EBAT	VRMS	91.493	89.537	87.483	85.613	81.493
19	EARM	VRMS	50.087	59.963	66.225	70.297	77.267
20	EFM	VRMS	40.403	37.510	32.356	26.983	3.256
21	IBAT′	ARMS	65.255	89.086	113.419	131.614	163.529
22	IARM	ARMS	71.897	95.844	119.360	135.201	164.381
23	ITH1	ARMS	66.443	89.797	114.971	133.432	165.400
24	ID2	ARMS	36.312	39.938	37.420	31.076	0.141
25	IC4	ARMS	32.999	35.346	33.701	27.984	0.120
26	ITH2	ARMS	25.708	27.964	26.728	22.980	0.024
27	ID4	ARMS	7.364	8.768	9.052	8.268	0.024
28	VCT1	VRMS	0.072	0.093	0.114	0.128	0.151
29	ETH1	VRMS	1.009	1.118	1.202	1.260	1.314
30	EDF2	VRMS	0.358	0.321	0.273	0.229	0.020
31	VC4	VRMS	69.586	74.884	73.075	69.276	30.461
32	PLBT	W	~~1338.225~~	~~1464.236~~	~~1172.657~~	~~1199.285~~	~~32.888~~
33	PLCOM	W	~~1959.835~~	~~1963.107~~	~~1761.681~~	~~1477.226~~	~~2.150~~
34	PLC4	W	61.312	32.559	32.593	28.128	4.868
35	VINT	VRMS	0.045	0.060	0.076	0.088	0.109
36	VINT	VDC	0.026	0.043	0.060	0.076	0.109

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112D; S.N.: 1276

79-06-22 16:45:34 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	4003.605	3997.343	3999.450
2	TMOT	FT-#	4.994	8.555	13.399
3	EBAT	VDC	90.191	88.392	86.009
4	EARM	VDC	62.895	72.760	83.116
5	EFM	VDC	0.928	0.726	1.074
6	IBAT´	ADC	47.400	68.970	98.609
7	IARM	ADC	52.895	72.450	99.031
8	ITH1	ADC	46.767	69.116	99.509
9	ID2	ADC	5.742	3.438	0.101
10	VCT1	VDC	0.049	0.067	0.091
11	ETH1	VDC	0.675	0.893	1.146
12	EDF2	VDC	0.091	0.044	0.021
13	PLABT	W	~~209.255~~	~~273.136~~	~~84.796~~
14	PLACOM	W	~~25.395~~	~~17.798~~	~~1.652~~
15	PLAC4	W	2.209	4.802	4.725
16	MOTR TEMP	C	49.832	51.302	52.605
17	CONTROLR	HZ	526.623	339.301	1.000
18	EBAT	VRMS	90.224	88.435	85.946
19	EARM	VRMS	63.688	73.311	83.123
20	EFM	VRMS	38.717	30.714	3.343
21	IBAT´	ARMS	64.413	80.802	98.535
22	IARM	ARMS	67.288	82.581	98.676
23	ITH1	ARMS	65.513	82.093	99.341
24	ID2	ARMS	24.672	20.402	0.181
25	IC4	ARMS	27.863	24.212	0.160
26	ITH2	ARMS	21.068	18.340	0.032
27	ID4	ARMS	7.760	7.416	0.036
28	VCT1	VRMS	0.068	0.080	0.091
29	ETH1	VRMS	1.141	1.219	1.138
30	EDF2	VRMS	0.274	0.215	0.021
31	VC4	VRMS	67.783	63.213	32.922
32	PLBT	W	~~1291.332~~	~~1723.571~~	~~17.377~~
33	PLCOM	W	~~1573.312~~	~~1312.493~~	~~2.306~~
34	PLC4	W	24.641	23.349	4.709
35	VINT	VRMS	0.044	0.054	0.065
36	VINT	VDC	0.031	0.046	0.065

(UN)
EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

79-05-23 11:29:01 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	MOTOR ROTOR SPEED
2	TMOT	FT-#	MOTOR SHAFT TORQUE
3	TMOT	N-m	MOTOR SHAFT TORQUE
4	PABAT	W	BATTERY POWER AVAILABLE AT TERMINAL, AVERAGE VALUE
5	IBAT	ADC	BATTERY CURRENT, AVERAGE VALUE
6	PBAT	W	BATTERY R.M.S. POWER AVAILABLE AT TERMINAL
7	IBAT	ARMS	BATTERY CURRENT, R.M.S. VALUE
8	DELTAMOT	PU	CHOPPER CONDUCTION DUTY CYCLE ΔMOT
9	DELTAD2	PU	DUTY CYCLE OF FREE WHEELING MODE ΔD2
10	DFM	VDC	MOTOR FIELD VOLTAGE, AVERAGE VALUE
11	PAMOT	W	AVERAGE POWER CONSUMPTION OF MOTOR
12	PTR	W	MOTOR POWER DELIVERED AT SHAFT
13	PMOT	W	R.M.S. POWER CONSUMPTION OF MOTOR
14	EFFAMOT	%	DC POWER TRANSFER EFFICIENCY OF MOTOR
15	WLAMT	W/N-m	MOTOR DC WATT-LOSS/TORQUE DELIVERED AT SHAFT
16	EFFMOT	%	MOTOR POWER TRANSFER EFFICIENCY BASED ON R.M.S. VALUES
17	WLMOT	W/N-m	MOTOR R.M.S. WATT-LOSS/TORQUE DELIVERED AT SHAFT
18	DEGM	%	MOTOR PERFORMANCE DEGRADATION IN PULSATING DC CURRENT MODE
19	PLMOT	W	HEAT LOSS IN MOTOR
20	PLCTR	W	HEAT LOSS IN DC CHOPPER PANEL
21	PACT	W	POWER LOSS ACROSS CONTACTOR C1
22	PCT	W	HEAT LOSS IN CONTACTOR C1
23	EMOT	VRMS	MOTOR VOLTAGE, R.M.S. VALUE
24	EFFCTR	%	POWER TRANSFER EFFICIENCY OF CONTROLLER
25	WLCTR	W/N-m	CONTROLLER WATT-LOSS/MOTOR TORQUE DELIVERED AT SHAFT
26	PATH1	W	AVERAGE POWER LOSS IN TH1
27	PAD2F	W	AVERAGE POWER LOSS IN D2
28	PTH1	W	HEAT DISSIPATION OF TH1
29	PD2F	W	HEAT DISSIPATION OF D2
30	PLCOM	W	HEAT DISSIPATION OF COMMUTATING CIRCUIT
31	PLABT	W	POWER LOSS WITHIN BATTERY WHEN DISCHARGING
32	PLBAT	W	HEAT DISSIPATION OF BATTERY WHEN DISCHARGING
33	PAEV	W	DC POWER FOR ELECTRIC DRIVE IN CONTINUOUS DC CURRENT MODE
34	EFFAEV	%	ELECTRIC DRIVE EFFICIENCY IN CONTINUOUS DC CURRENT MODE
35	PEV	W	R.M.S. POWER FOR ELECTRIC DRIVE IN PULSATING DC CURRENT MODE
36	EFFEV	%	ELECTRIC SYSTEM EFFICIENCY IN PULSATING DC CURRENT MODE
37	WLEV	PU	ELECTRIC SYSTEM WATT-LOSS/WATT DELIVERED AT MOTOR SHAFT
38	PHEAT	W	HEAT DISSIPATION OF ELECTRIC SYSTEM
39	DEGEV	%	SYSTEM PERFORMANCE DEGRADATION FOR PULSATING DC CURRENT MODE
40	DELTABT	VDC	VOLTAGE DROP WITHIN BATTERY, AVERAGE VALUE
41	EBATO	VDC	OPEN CIRCUIT BATTERY VOLTAGE, PEAK AMPLITUDE
42	PLACTR	W	POWER LOSS IN CHOPPER PANEL, AVERAGE VALUE
43	PLACOM	W	POWER LOSS IN COMMUTATING CIRCUIT, AVERAGE VALUE

Table D2. Nomenclature for Calculated Data, Parametric Chopper and Motor Test.

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE

79-05-11 11:25:00 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1638.459	1640.059	1638.571	1642.319	1636.567	1637.213
2	TMOT	FT-#	4.483	8.800	12.909	17.677	22.294	28.567
3	TMOT	N-m	6.078	11.932	17.503	23.967	30.227	38.732
4	PABAT	W	2268.658	3599.493	4802.309	6185.099	7740.251	9654.374
5	IBAT	ADC	24.140	38.863	52.438	68.490	86.881	110.592
6	PBAT	W	5291.785	7026.248	8694.762	10550.693	12300.265	14491.143
7	IBAT	ARMS	56.325	75.789	94.840	116.613	137.809	165.464
8	DELTAMOT	PU	0.184	0.263	0.306	0.345	0.397	0.447
9	DELTAD2	PU	0.816	0.737	0.694	0.655	0.603	0.553
10	DFM	VDC	1.169	1.146	1.500	1.646	2.005	2.307
11	PAMOT	W	1340.284	2436.845	3495.998	4686.690	5957.693	7663.161
12	PTR	W	1042.880	2049.300	3003.402	4122.026	5180.440	6640.733
13	PMOT	W	2803.363	4238.945	5558.216	7040.876	8371.264	10182.398
14	EFFAMOT	%	77.810	84.096	85.910	87.952	86.954	86.658
15	WLAMT	W/N-m	48.932	32.480	28.144	23.560	25.714	26.398
16	EFFMOT	%	37.201	48.345	54.035	58.544	61.884	65.218
17	WLMOT	W/N-m	289.652	183.515	145.967	121.787	105.564	91.441
18	DEGM	%	52.190	42.513	37.102	33.436	28.832	24.741
19	PLMOT	W	1760.482	2189.645	2554.814	2918.850	3190.823	3541.665
20	PLCTR	W	2484.021	2779.233	3124.180	3491.615	3904.201	4274.063
21	PACT	W	2.324	5.270	8.855	13.803	19.888	29.401
22	PCT	W	5.371	10.019	15.295	22.026	29.856	41.049
23	EMOT	VRMS	38.494	42.527	45.171	47.549	48.821	50.714
24	EFFCTR	%	52.976	60.330	63.926	66.734	68.058	70.266
25	WLCTR	W/N-m	408.696	232.929	178.497	145.686	129.165	110.350
26	PATH1	W	7.301	16.331	26.668	39.904	55.690	84.014
27	PAD2F	W	9.115	14.033	16.900	18.209	18.628	18.465
28	PTH1	W	51.239	77.359	101.749	128.663	158.243	199.385
29	PD2F	W	27.887	37.746	44.557	49.580	53.865	56.899
30	PLCOM	W	2399.523	2654.109	2962.578	3291.346	3662.237	3976.729
31	PLABT	W	53.689	139.200	242.354	403.863	617.889	984.870
32	PLBAT	W	292.283	529.402	792.766	1170.764	1554.602	2204.635
33	PAEV	W	2322.347	3738.692	5044.663	6588.963	8358.140	10639.244
34	EFFAEV	%	44.906	54.813	59.536	62.560	61.981	62.417
35	PEV	W	5584.067	7555.650	9487.529	11721.457	13854.867	16695.778
36	EFFEV	%	18.676	27.123	31.656	35.166	37.391	39.775
37	WLEV	PU	4.354	2.687	2.159	1.844	1.674	1.514
38	PHEAT	W	4244.503	4968.878	5678.994	6410.465	7095.025	7815.728
39	DEGEV	%	58.411	50.518	46.828	43.787	39.674	36.276
40	DELTABT	VDC	2.224	3.582	4.622	5.897	7.112	8.905
41	EBAT0	VDC	96.203	96.203	96.203	96.203	96.203	96.203
42	PLACTR	W	926.776	1158.984	1300.066	1488.584	1768.173	1969.435
43	PLACOM	W	908.035	1123.351	1247.643	1416.668	1673.967	1837.556

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE

79-05-11 10:57:30 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	83.739	51.939	52.176	46.255	53.394	55.314
2	TMOT	FT-#	4.655	8.631	13.443	17.173	21.779	27.140
3	TMOT	N-m	6.311	11.702	18.227	23.283	29.529	36.796
4	PABAT	W	433.502	663.593	978.990	1316.865	1743.965	2290.352
5	IBAT	ADC	4.201	6.576	9.946	13.642	18.341	24.412
6	PBAT	W	2423.274	3390.682	4431.885	5299.785	6318.918	7713.951
7	IBAT	ARMS	23.529	33.672	45.087	54.973	66.453	82.154
8	DELTAMOT	PU	0.032	0.038	0.049	0.062	0.076	0.088
9	DELTAD2	PU	0.968	0.962	0.951	0.938	0.924	0.912
10	DFM	VDC	0.892	1.832	1.582	2.017	2.443	2.672
11	PAMOT	W	111.683	296.375	454.900	642.065	916.709	1253.516
12	PTR	W	55.344	63.652	99.591	112.781	165.111	213.148
13	PMOT	W	174.743	413.662	591.597	881.694	1155.132	1569.016
14	EFFAMOT	%	49.554	21.477	21.893	17.565	18.011	17.004
15	WLAMT	W/N-m	8.927	19.887	19.494	22.733	25.453	28.274
16	EFFMOT	%	31.672	15.387	16.834	12.791	14.294	13.585
17	WLMOT	W/N-m	18.919	29.909	26.994	33.025	33.528	36.848
18	DEGM	%	36.087	28.353	23.106	27.178	20.640	20.108
19	PLMOT	W	119.399	350.010	492.006	768.913	990.021	1355.868
20	PLCTR	W	2246.575	2972.680	3832.611	4406.900	5148.252	6122.751
21	PACT	W	2.206	5.192	9.466	13.243	19.494	27.730
22	PCT	W	3.496	7.600	13.121	19.011	25.901	36.921
23	EMOT	VRMS	3.310	4.999	5.321	6.572	7.275	8.317
24	EFFCTR	%	7.211	12.200	13.349	16.636	18.281	20.340
25	WLCTR	W/N-m	355.978	254.022	210.275	189.278	174.348	166.397
26	PATH1	W	0.262	0.423	0.912	1.537	2.328	3.560
27	PAD2F	W	28.419	42.100	57.945	69.372	79.406	94.439
28	PTH1	W	7.283	12.232	18.063	24.082	31.503	42.451
29	PD2F	W	36.368	55.108	73.506	88.028	102.416	118.628
30	PLCOM	W	2199.427	2897.740	3727.921	4275.779	4988.432	5924.751
31	PLABT	W	16.842	41.335	87.286	145.605	222.224	326.719
32	PLBAT	W	528.349	1083.875	1793.540	2364.362	2917.270	3700.106
33	PAEV	W	450.344	704.927	1066.276	1462.470	1966.189	2617.071
34	EFFAEV	%	12.289	9.030	9.340	7.712	8.398	8.145
35	PEV	W	2951.623	4474.557	6225.425	7664.147	9236.189	11414.057
36	EFFEV	%	1.875	1.423	1.600	1.472	1.788	1.867
37	WLEV	PU	52.333	69.297	61.510	66.956	54.939	52.550
38	PHEAT	W	2365.974	3322.690	4324.617	5175.813	6138.273	7478.619
39	DEGEV	%	84.742	84.246	82.872	80.918	78.712	77.072
40	DELTABT	VDC	4.009	6.286	8.776	10.673	12.116	13.383
41	EBATO	VDC	107.203	107.203	107.203	107.203	107.203	107.203
42	PLACTR	W	320.823	364.606	519.066	667.855	816.743	1021.830
43	PLACCM	W	289.936	316.891	450.744	583.704	715.515	896.101

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE

79-05-11 11:03:00 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	202.308	199.172	197.473	203.871	196.461	201.611
2	TMOT	FT-#	4.833	8.651	12.834	17.103	22.710	27.457
3	TMOT	N-m	6.552	11.729	17.401	23.188	30.790	37.226
4	PABAT	W	672.945	962.447	1379.588	1869.950	2463.868	3125.568
5	IBAT	ADC	6.783	9.868	14.404	19.789	26.335	33.693
6	PBAT	W	3020.131	3932.568	4998.493	6099.859	7519.156	8910.123
7	IBAT	ARMS	30.503	40.363	52.237	64.543	80.313	95.918
8	DELTAMOT	PU	0.049	0.060	0.076	0.094	0.108	0.123
9	DELTAD2	PU	0.951	0.940	0.924	0.906	0.892	0.877
10	DFM	VDC	0.693	1.298	1.467	2.192	2.402	2.595
11	PAMOT	W	221.503	440.783	687.365	1029.752	1443.394	1852.650
12	PTR	W	138.815	244.634	359.851	495.065	633.483	785.965
13	PMOT	W	319.753	656.178	969.327	1449.541	1889.949	2375.795
14	EFFAMOT	%	62.670	55.500	52.352	48.076	43.888	42.424
15	WLAMT	W/N-m	12.620	16.724	18.822	23.059	26.304	28.654
16	EFFMOT	%	43.413	37.282	37.124	34.153	33.519	33.082
17	WLMOT	W/N-m	27.615	35.089	35.026	41.163	40.807	42.708
18	DEGM	%	30.727	32.826	29.088	28.960	23.628	22.020
19	PLMOT	W	180.938	411.544	609.475	954.476	1256.465	1589.830
20	PLCTR	W	2698.036	3271.564	4021.047	4638.211	5611.115	6510.177
21	PACT	W	2.101	4.703	8.427	12.699	20.375	28.005
22	PCT	W	3.539	7.351	12.404	18.682	28.004	37.361
23	EMOT	VRMS	5.463	7.627	8.622	10.510	11.247	12.296
24	EFFCTR	%	10.587	16.686	19.392	23.764	25.135	26.664
25	WLCTR	W/N-m	411.782	278.940	231.083	200.026	182.236	174.883
26	PATH1	W	0.528	1.069	1.870	2.974	4.821	7.510
27	PAD2F	W	27.705	40.753	52.676	62.011	74.651	84.501
28	PTH1	W	12.538	18.820	26.258	34.205	46.375	59.763
29	PD2F	W	36.724	53.458	69.748	84.073	100.942	114.776
30	PLCOM	W	2645.234	3191.935	3912.636	4501.251	5435.795	6298.278
31	PLABT	W	24.888	52.717	102.273	165.915	245.344	340.669
32	PLBAT	W	503.283	882.019	1345.069	1764.912	2281.898	2760.901
33	PAEV	W	697.834	1015.164	1481.861	2035.865	2709.212	3466.237
34	EFFAEV	%	19.892	24.098	24.284	24.317	23.383	22.675
35	PEV	W	3523.413	4814.587	6343.563	7864.771	9801.053	11571.025
36	EFFEV	%	3.940	5.081	5.673	6.295	6.463	6.734
37	WLEV	PU	24.382	18.681	16.628	14.886	14.472	13.849
38	PHEAT	W	2878.974	3683.107	4630.522	5592.687	6867.581	8100.007
39	DEGEV	%	80.194	78.915	76.640	74.114	72.358	70.300
40	DELTABT	VDC	3.669	5.342	7.100	8.384	9.316	10.111
41	EBATO	VDC	102.877	102.877	102.877	102.877	102.877	102.877
42	PLACTR	W	450.164	519.000	687.444	833.020	1008.981	1257.335
43	PLACOM	W	419.830	472.475	624.472	755.336	909.133	1137.318

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE

79-05-11 11:07:23 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	667.682	667.357	667.609	668.428	671.419	665.263
2	TMOT	FT-#	4.496	8.626	13.279	19.269	22.337	27.840
3	TMOT	N-m	6.096	11.696	18.004	26.125	30.285	37.745
4	PABAT	W	1311.960	1877.604	2620.482	3657.701	4226.874	5432.319
5	IBAT	ADC	13.562	19.850	28.011	39.554	45.948	59.563
6	PBAT	W	3930.704	5206.262	6750.001	8395.211	9719.277	11386.640
7	IBAT	ARMS	40.718	55.064	72.139	90.694	105.470	124.519
8	DELTAMOT	PU	0.111	0.130	0.151	0.190	0.190	0.229
9	DELTAD2	PU	0.889	0.870	0.849	0.810	0.810	0.771
10	DFM	VDC	0.625	1.431	1.608	2.057	1.982	2.359
11	PAMOT	W	547.705	1065.270	1644.307	2412.967	2845.658	3640.292
12	PTR	W	426.220	817.387	1258.710	1828.735	2129.412	2629.672
13	PMOT	W	1064.596	1711.855	2455.917	3343.200	3924.087	4780.163
14	EFFAMOT	%	77.819	76.730	76.550	75.788	74.830	72.238
15	WLAMT	W/N-m	19.930	21.194	21.418	22.363	23.650	26.775
16	EFFMOT	%	40.036	47.749	51.252	54.700	54.265	55.012
17	WLMOT	W/N-m	104.726	76.479	66.498	57.970	59.260	56.974
18	DEGM	%	48.553	37.771	33.047	27.825	27.482	23.846
19	PLMOT	W	638.376	894.468	1197.207	1514.465	1794.675	2150.491
20	PLCTR	W	2862.729	3488.287	4283.807	5035.989	5774.387	6578.169
21	PACT	W	2.494	5.505	9.967	16.600	22.125	31.276
22	PCT	W	5.086	9.392	15.801	24.410	31.647	42.749
23	EMOT	VRMS	15.657	18.423	20.244	22.106	22.897	24.023
24	EFFCTR	%	27.084	32.881	36.384	39.823	40.374	41.980
25	WLCTR	W/N-m	469.634	298.254	237.941	192.767	190.670	174.277
26	PATH1	W	1.892	3.976	7.145	12.628	16.185	22.797
27	PAD2F	W	21.824	30.761	39.616	47.794	52.048	59.121
28	PTH1	W	28.739	39.852	53.535	72.033	86.597	108.616
29	PD2F	W	37.025	50.907	64.966	80.697	87.185	98.676
30	PLCOM	W	2791.879	3388.137	4149.505	4858.850	5568.958	6328.128
31	PLABT	W	62.727	134.461	218.843	351.599	430.547	605.147
32	PLBAT	W	565.444	1034.691	1451.432	1848.549	2268.548	2644.740
33	PAEV	W	1374.687	2012.065	2839.325	4009.300	4657.420	6037.467
34	EFFAEV	%	31.005	40.624	44.331	45.612	45.721	43.556
35	PEV	W	4496.149	6240.953	8201.433	10243.760	11987.825	14031.379
36	EFFEV	%	9.480	13.097	15.347	17.852	17.763	18.741
37	WLEV	PU	9.549	6.635	5.516	4.602	4.630	4.336
38	PHEAT	W	3501.106	4382.755	5481.014	6550.455	7569.062	8728.660
39	DEGEV	%	69.425	67.760	65.380	60.861	61.149	56.972
40	DELTABT	VDC	4.625	6.774	7.813	8.889	9.370	10.160
41	EBATO	VDC	101.363	101.363	101.363	101.363	101.363	101.363
42	PLACTR	W	762.933	809.372	970.716	1235.457	1369.214	1774.836
43	PLACOM	W	736.723	769.129	913.988	1158.436	1278.856	1661.641

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE

79-05-11 11:11:45 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	838.306	835.994	839.080	839.840	831.771	839.557
2	TMOT	FT-#	4.531	9.443	13.206	17.552	21.933	26.474
3	TMOT	N-m	6.144	12.802	17.905	23.798	29.737	35.894
4	PABAT	W	1509.058	2355.117	3009.273	3944.380	4848.751	5850.608
5	IBAT	ADC	15.663	24.959	32.230	42.628	52.831	64.353
6	PBAT	W	4293.645	5916.504	7250.560	8629.701	10101.951	11700.777
7	IBAT	ARMS	44.665	62.730	77.564	93.085	109.855	128.394
8	DELTAMOT	PU	0.123	0.158	0.173	0.210	0.231	0.251
9	DELTAD2	PU	0.877	0.842	0.827	0.790	0.769	0.749
10	DFM	VDC	1.428	1.548	1.825	1.587	2.009	2.482
11	PAMOT	W	720.449	1410.850	1989.528	2623.022	3314.135	4112.924
12	PTR	W	539.365	1120.809	1573.335	2093.013	2590.292	3155.820
13	PMOT	W	1450.188	2357.526	3092.386	3754.982	4632.442	5548.404
14	EFFAMOT	%	74.865	79.442	79.081	79.794	78.159	76.729
15	WLAMT	W/N-m	29.474	22.656	23.245	22.272	24.341	26.665
16	EFFMOT	%	37.193	47.542	50.878	55.740	55.916	56.878
17	WLMOT	W/N-m	148.251	96.602	84.839	69.838	68.673	66.657
18	DEGM	%	50.320	40.155	35.664	30.146	28.458	25.872
19	PLMOT	W	910.824	1236.717	1519.051	1661.969	2042.149	2392.584
20	PLCTR	W	2839.811	3551.708	4147.342	4859.190	5448.495	6124.965
21	PACT	W	2.406	5.920	9.495	14.619	20.174	26.926
22	PCT	W	5.115	10.463	15.759	22.056	29.731	38.319
23	EMOT	VRMS	20.756	23.516	25.184	25.658	27.281	28.836
24	EFFCTR	%	33.775	39.847	42.650	43.512	45.857	47.419
25	WLCTR	W/N-m	462.225	277.430	231.630	204.189	183.221	170.642
26	PATH1	W	2.524	6.195	9.919	14.082	20.540	28.033
27	PAD2F	W	19.254	28.972	34.768	40.517	44.762	48.547
28	PTH1	W	34.035	49.579	62.294	79.377	97.365	119.186
29	PD2F	W	35.749	51.788	61.492	71.314	80.653	88.835
30	PLCOM	W	2764.912	3439.879	4007.797	4686.444	5240.746	5878.625
31	PLABT	W	52.298	132.874	203.420	304.800	417.471	564.160
32	PLBAT	W	425.261	839.303	1178.166	1453.411	1805.080	2245.718
33	PAEV	W	1561.356	2487.990	3212.693	4249.180	5266.223	6414.768
34	EFFAEV	%	34.545	45.049	48.972	49.257	49.187	49.196
35	PEV	W	4718.906	6755.806	8428.726	10083.112	11907.031	13946.495
36	EFFEV	%	11.430	16.590	18.666	20.758	21.754	22.628
37	WLEV	PU	7.749	5.028	4.357	3.818	3.597	3.419
38	PHEAT	W	3750.634	4788.426	5666.392	6521.160	7490.644	8517.549
39	DEGEV	%	66.913	63.173	61.884	57.858	55.772	54.004
40	DELTABT	VDC	3.339	5.324	6.312	7.150	7.902	8.767
41	EBATO	VDC	99.681	99.681	99.681	99.681	99.681	99.681
42	PLACTR	W	787.246	940.869	1014.201	1312.818	1522.630	1721.552
43	PLACOM	W	763.062	899.782	960.019	1243.598	1437.154	1618.046

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE

79-05-11 11:16:06 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1048.524	1046.037	1048.154	1046.017	1044.684	1044.216
2	TMOT	FT-#	4.586	9.883	12.864	17.480	21.830	28.115
3	TMOT	N-m	6.218	13.399	17.442	23.700	29.597	38.118
4	PABAT	W	1742.125	2647.113	3496.194	4522.092	5587.550	7015.264
5	IBAT	ADC	18.257	28.238	37.606	49.151	61.332	78.055
6	PBAT	W	4649.888	6430.272	7599.693	9249.034	10782.165	12862.943
7	IBAT	ARMS	48.812	68.575	81.650	100.349	118.077	142.654
8	DELTAMOT	PU	0.140	0.170	0.212	0.240	0.270	0.299
9	DELTAD2	PU	0.860	0.830	0.788	0.760	0.730	0.701
10	DFM	VDC	1.021	1.618	1.872	1.985	1.852	2.435
11	PAMOT	W	905.529	1808.313	2354.576	3215.631	3974.863	5167.189
12	PTR	W	682.781	1467.806	1914.495	2596.158	3237.967	4168.343
13	PMOT	W	1808.865	2935.890	3710.320	4655.439	5560.406	6868.854
14	EFFAMOT	%	75.401	81.170	81.310	80.736	81.461	80.669
15	WLAMT	W/N-m	35.822	25.413	25.232	26.138	24.898	26.204
16	EFFMOT	%	37.746	49.995	51.599	55.766	58.233	60.685
17	WLMOT	W/N-m	181.097	109.565	102.962	86.889	78.469	70.846
18	DEGM	%	49.939	38.407	36.540	30.927	28.515	24.774
19	PLMOT	W	1126.084	1468.084	1795.825	2059.280	2322.439	2700.511
20	PLCTR	W	2837.014	3486.373	3878.268	4577.237	5199.753	5963.332
21	PACT	W	2.504	6.238	9.136	14.495	20.475	29.585
22	PCT	W	5.468	10.969	15.312	22.507	30.006	41.233
23	EMOT	VRMS	24.848	28.378	30.441	31.556	32.657	34.448
24	EFFCTR	%	38.901	45.657	48.822	50.334	51.570	53.400
25	WLCTR	W/N-m	456.249	260.193	222.358	193.132	175.687	156.444
26	PATH1	W	3.878	8.368	12.786	20.074	27.580	41.152
27	PAD2F	W	16.342	25.823	28.915	34.528	37.178	40.320
28	PTH1	W	39.748	60.035	72.594	92.801	113.935	145.888
29	PD2F	W	35.045	49.292	56.806	66.551	73.874	82.600
30	PLCOM	W	2756.753	3366.077	3733.557	4395.377	4981.939	5693.610
31	PLABT	W	55.997	134.041	207.605	318.807	453.071	672.429
32	PLBAT	W	400.273	790.506	978.669	1328.875	1679.255	2245.982
33	PAEV	W	1798.122	2781.155	3703.799	4840.899	6040.621	7687.694
34	EFFAEV	%	37.972	52.777	51.690	53.630	53.603	54.221
35	PEV	W	5050.161	7220.778	8578.363	10577.909	12461.420	15108.924
36	EFFEV	%	13.520	20.328	22.318	24.543	25.984	27.589
37	WLEV	PU	6.396	3.919	3.481	3.074	2.849	2.625
38	PHEAT	W	3963.097	4954.456	5674.093	6636.517	7522.192	8663.842
39	DEGEV	%	64.395	61.484	56.824	54.236	51.525	49.118
40	DELTABT	VDC	3.067	4.747	5.521	6.486	7.387	8.615
41	EBATO	VDC	98.490	98.490	98.490	98.490	98.490	98.490
42	PLACTR	W	835.065	835.009	1136.105	1297.528	1600.206	1829.675
43	PLACOM	W	812.340	794.579	1085.269	1228.431	1514.973	1718.618

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE

79-05-11 11:20:44 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	1310.714	1306.036	1305.814	1303.291	1303.788	1301.771
2	TMOT	FT-#	4.775	8.711	12.863	18.194	21.704	28.207
3	TMOT	N-m	6.474	11.810	17.440	24.668	29.426	38.243
4	PABAT	W	2070.418	3016.249	3992.598	5411.071	6355.133	8185.628
5	IBAT	ADC	21.863	32.297	43.211	59.333	70.362	92.197
6	PBAT	W	4785.595	6465.367	8074.911	10007.073	11332.282	13588.136
7	IBAT	ARMS	50.595	69.202	87.295	109.527	125.159	152.504
8	DELTAMOT	PU	0.187	0.218	0.245	0.293	0.316	0.365
9	DELTAD2	PU	0.813	0.782	0.755	0.707	0.684	0.635
10	DFM	VDC	1.123	1.600	1.479	1.765	2.023	2.377
11	PAMOT	W	1084.873	1963.194	2807.295	3944.567	4752.802	6247.727
12	PTR	W	888.702	1615.348	2384.904	3366.816	4017.742	5213.466
13	PMOT	W	2256.491	3396.241	4454.410	5799.978	6738.297	8315.917
14	EFFAMOT	%	81.918	82.282	84.954	85.353	84.534	83.446
15	WLAMT	W/N-m	30.299	29.452	24.220	23.421	24.980	27.045
16	EFFMOT	%	39.384	47.563	53.540	58.049	59.625	62.693
17	WLMOT	W/N-m	211.259	150.789	118.665	98.636	92.454	81.125
18	DEGM	%	51.922	42.195	36.977	31.990	29.466	24.870
19	PLMOT	W	1367.789	1780.893	2069.506	2433.162	2720.554	3102.451
20	PLCTR	W	2525.004	3061.714	3608.940	4189.252	4571.391	5239.937
21	PACT	W	2.656	5.884	10.028	16.096	20.967	30.718
22	PCT	W	5.964	10.964	16.937	25.016	31.030	42.698
23	EMOT	VRMS	31.277	34.678	36.474	38.532	39.916	41.592
24	EFFCTR	%	47.152	52.530	55.164	57.959	59.461	61.200
25	WLCTR	W/N-m	389.994	259.237	206.935	169.825	155.352	137.018
26	PATH1	W	5.298	10.748	17.970	28.807	38.079	57.301
27	PAD2F	W	12.258	19.439	23.369	26.449	28.216	29.571
28	PTH1	W	47.326	64.988	85.040	111.952	131.028	168.526
29	PD2F	W	32.213	42.452	51.519	59.973	64.626	71.592
30	PLCOM	W	2439.601	2943.309	3455.444	3992.311	4344.707	4957.121
31	PLABT	W	59.897	130.770	217.855	370.257	500.859	797.969
32	PLBAT	W	320.772	600.371	889.123	1261.715	1584.780	2183.326
33	PAEV	W	2130.315	3147.019	4210.453	5781.328	6855.992	8983.597
34	EFFAEV	%	41.717	51.329	56.642	58.236	58.602	58.033
35	PEV	W	5106.367	7065.738	8964.034	11268.789	12917.062	15771.462
36	EFFEV	%	17.404	22.862	26.605	29.877	31.104	33.056
37	WLEV	PU	4.746	3.374	2.759	2.347	2.215	2.025
38	PHEAT	W	3892.793	4842.607	5678.446	6622.414	7291.945	8342.388
39	DEGEV	%	58.281	55.461	53.029	48.696	46.923	43.039
40	DELTABT	VDC	2.740	4.049	5.042	6.240	7.118	8.655
41	EBAT0	VDC	97.439	97.439	97.439	97.439	97.439	97.439
42	PLACTR	W	984.035	1049.698	1179.543	1456.842	1589.516	1918.212
43	PLACOM	W	963.823	1013.627	1128.177	1385.490	1502.254	1800.123

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE

79-05-11 11:29:34 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	2049.558	2049.695	2048.924	2046.712	2049.481	2047.546
2	TMOT	FT-#	4.254	9.070	13.678	17.974	22.067	27.685
3	TMOT	N-m	5.768	12.297	18.544	24.369	29.919	37.535
4	PABAT	W	2651.719	4324.116	5900.545	7491.328	8905.767	11115.995
5	IBAT	ADC	28.259	47.119	65.284	84.187	101.714	129.699
6	PBAT	W	5565.985	7717.001	9641.843	11377.575	12917.088	14976.193
7	IBAT	ARMS	59.409	84.075	106.560	127.629	147.200	174.215
8	DELTAMOT	PU	0.226	0.314	0.375	0.435	0.477	0.554
9	DELTAD2	PU	0.774	0.686	0.625	0.565	0.523	0.446
10	DFM	VDC	0.789	1.514	1.540	2.053	1.839	2.217
11	PAMOT	W	1583.393	3154.114	4544.041	5919.568	7148.144	9081.221
12	PTR	W	1238.053	2639.530	3979.017	5223.285	6421.411	8048.543
13	PMOT	W	3577.320	5496.023	7239.422	8784.765	10181.616	12042.280
14	EFFAMOT	%	78.190	83.685	87.566	88.238	89.833	88.628
15	WLAMT	W/N-m	59.870	41.847	30.469	28.572	24.290	27.512
16	EFFMOT	%	34.608	48.026	54.963	59.458	63.069	66.836
17	WLMOT	W/N-m	405.550	232.295	175.819	146.146	125.681	106.400
18	DEGM	%	55.738	42.611	37.232	32.616	29.794	24.589
19	PLMOT	W	2339.267	2856.493	3260.405	3561.480	3760.205	3993.738
20	PLCTR	W	1983.988	2211.958	2388.228	2572.967	2709.338	2898.586
21	PACT	W	2.714	6.617	11.038	15.833	20.828	29.125
22	PCT	W	6.395	12.262	18.596	24.578	30.901	39.469
23	EMOT	VRMS	48.050	53.341	56.365	58.448	59.750	61.270
24	EFFCTR	%	64.271	71.220	75.083	77.211	78.823	80.409
25	WLCTR	W/N-m	343.957	179.880	128.786	105.582	90.557	77.223
26	PATH1	W	9.887	24.519	41.955	59.973	82.165	118.375
27	PAD2F	W	5.581	8.956	10.291	10.399	10.019	8.618
28	PTH1	W	56.913	87.791	122.054	150.221	182.846	226.370
29	PD2F	W	23.251	31.260	36.102	38.969	39.922	38.716
30	PLCOM	W	1897.429	2080.646	2211.477	2359.198	2455.669	2594.031
31	PLABT	W	87.422	243.169	427.440	669.014	953.405	1455.823
32	PLBAT	W	386.386	774.193	1138.814	1537.578	1996.801	2626.667
33	PAEV	W	2739.142	4567.284	6327.984	8160.342	9859.172	12571.818
34	EFFAEV	%	45.199	57.792	62.880	64.008	65.131	64.021
35	PEV	W	5952.371	8491.193	10780.657	12915.153	14913.889	17602.859
36	EFFEV	%	20.799	31.085	36.909	40.443	43.057	45.723
37	WLEV	PU	3.808	2.217	1.709	1.473	1.323	1.187
38	PHEAT	W	4323.255	5068.451	5648.633	6134.447	6469.543	6892.324
39	DEGEV	%	53.982	46.212	41.302	36.816	33.893	28.581
40	DELTABT	VDC	3.094	5.161	6.547	7.947	9.373	11.225
41	EBATO	VDC	96.931	96.931	96.931	96.931	96.931	96.931
42	PLACTR	W	1066.676	1165.784	1349.054	1560.452	1741.846	2011.322
43	PLACOM	W	1048.493	1125.693	1285.720	1474.247	1628.834	1855.204

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE

79-05-11 12:47:47 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	2559.924	2560.091	2560.769	2560.056	2560.980	2559.902
2	TMOT	FT-#	4.398	8.871	13.255	17.416	21.777	27.355
3	TMOT	N-m	5.963	12.027	17.971	23.612	29.525	37.088
4	PABAT	W	3166.570	5033.376	6774.246	8616.510	10334.210	12522.299
5	IBAT	ADC	34.229	55.480	75.990	98.487	120.495	150.202
6	PBAT	W	5855.537	8035.132	9906.496	11626.114	13260.976	15021.999
7	IBAT	ARMS	63.295	88.481	111.023	132.630	154.397	179.887
8	DELTAMOT	PU	0.292	0.393	0.468	0.551	0.609	0.697
9	DELTAD2	PU	0.708	0.607	0.532	0.449	0.391	0.303
10	DFM	VDC	0.773	1.270	1.308	1.331	1.751	2.216
11	PAMOT	W	2068.126	3786.906	5411.433	7039.832	8739.160	11001.101
12	PTR	W	1598.651	3224.408	4819.290	6330.418	7918.441	9942.644
13	PMOT	W	4324.547	6575.614	8508.994	10082.845	11805.721	13607.832
14	EFFAMOT	%	77.300	85.146	89.058	89.923	90.609	90.379
15	WLAMT	W/N-m	78.728	46.770	32.950	30.044	27.797	28.539
16	EFFMOT	%	36.967	49.036	56.638	62.784	67.073	73.066
17	WLMOT	W/N-m	457.116	278.644	205.316	158.918	131.661	98.824
18	DEGM	%	52.177	42.410	36.403	30.180	25.975	19.156
19	PLMOT	W	2725.896	3351.206	3689.704	3752.428	3887.280	3665.188
20	PLCTR	W	1526.087	1450.343	1383.196	1523.392	1428.862	1379.223
21	PACT	W	2.405	5.413	9.290	14.035	19.397	27.421
22	PCT	W	5.600	10.225	15.437	21.028	27.136	34.663
23	EMOT	VRMS	58.260	65.031	68.172	69.193	71.033	71.973
24	EFFCTR	%	73.854	81.836	85.893	86.726	89.026	90.586
25	WLCTR	W/N-m	255.915	120.592	76.969	64.517	48.395	37.188
26	PATH1	W	14.612	33.713	57.394	86.678	118.516	169.633
27	PAD2F	W	3.849	4.648	4.482	3.818	2.985	1.754
28	PTH1	W	61.934	94.868	130.664	165.536	203.585	247.501
29	PD2F	W	18.432	22.348	23.616	23.238	21.579	16.838
30	PLCOM	W	1440.121	1322.902	1213.479	1313.590	1176.561	1080.221
31	PLABT	W	98.340	258.451	473.949	777.482	1158.976	1804.497
32	PLBAT	W	336.258	657.372	1011.686	1410.007	1902.895	2588.230
33	PAEV	W	3264.910	5291.827	7248.195	9393.992	11493.186	14326.796
34	EFFAEV	%	48.965	60.932	66.490	67.388	68.897	69.399
35	PEV	W	6191.795	8692.504	10918.182	13036.122	15163.871	17610.229
36	EFFEV	%	25.819	37.094	44.140	48.561	52.219	56.459
37	WLEV	PU	2.873	1.696	1.266	1.059	0.915	0.771
38	PHEAT	W	4251.983	4801.549	5072.900	5275.820	5316.142	5044.411
39	DEGEV	%	47.270	39.122	33.614	27.939	24.207	18.645
40	DELTABT	VDC	2.873	4.658	6.237	7.894	9.618	12.014
41	EBATO	VDC	95.383	95.383	95.383	95.383	95.383	95.383
42	PLACTR	W	1096.520	1241.966	1354.866	1564.166	1577.225	1494.796
43	PLACOM	W	1075.654	1198.193	1283.700	1459.634	1436.327	1295.988

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE

79-05-11   12:52:03   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	3199.838	3198.573	3201.180	3198.121	3196.525
2	TMOT	FT-#	4.521	8.746	13.475	17.728	26.413
3	TMOT	N-m	6.129	11.858	18.270	24.036	35.811
4	PABAT	W	3665.494	5700.165	7881.433	9655.529	13329.194
5	IBAT	ADC	40.051	63.668	90.167	112.908	163.350
6	PBAT	W	5963.440	7963.887	9902.011	11241.041	13285.784
7	IBAT	ARMS	65.179	88.945	113.188	131.301	163.030
8	DELTAMOT	PU	0.378	0.512	0.635	0.739	1.004
9	DELTAD2	PU	0.622	0.488	0.365	0.261	-0.004
10	DFM	VDC	0.731	0.788	1.363	1.615	1.869
11	PAMOT	W	2610.379	4565.239	6753.314	8601.723	13064.114
12	PTR	W	2053.887	3971.917	6124.742	8049.947	11987.886
13	PMOT	W	4935.025	7257.205	9485.814	10848.384	12962.894
14	EFFAMOT	%	78.682	87.003	90.692	93.585	91.762
15	WLAMT	W/N-m	90.793	50.037	34.405	22.957	30.053
16	EFFMOT	%	41.619	54.731	64.567	74.204	92.479
17	WLMOT	W/N-m	470.066	277.060	183.969	116.429	27.225
18	DEGM	%	47.105	37.094	28.806	20.710	-0.781
19	PLMOT	W	2881.137	3285.288	3361.072	2798.437	975.009
20	PLCTR	W	1023.585	697.991	402.366	374.493	295.525
21	PACT	W	2.417	5.179	9.257	13.554	25.175
22	PCT	W	5.149	8.909	13.558	17.239	24.868
23	EMCT	VRMS	68.678	75.747	79.492	80.247	78.879
24	EFFCTR	%	82.755	91.126	95.797	96.507	97.570
25	WLCTR	W/N-m	167.001	58.864	22.024	15.581	8.252
26	PATH1	W	20.712	47.586	83.888	121.651	219.690
27	PAD2F	W	1.937	1.607	0.880	0.365	0.002
28	PTH1	W	67.042	100.397	138.169	168.133	217.271
29	PD2F	W	13.003	12.811	10.233	7.111	0.003
30	PLCOM	W	938.391	575.875	240.406	182.010	53.384
31	PLABT	W	135.040	341.393	674.646	1058.439	2171.329
32	PLBAT	W	357.638	666.277	1063.110	1431.368	2162.814
33	PAEV	W	3800.534	6041.559	8556.079	10713.968	15500.523
34	EFFAEV	%	54.042	65.743	71.584	75.135	77.339
35	PEV	W	6321.078	8630.164	10965.122	12672.410	15448.598
36	EFFEV	%	32.493	46.024	55.857	63.523	77.599
37	WLEV	PU	2.078	1.173	0.790	0.574	0.289
38	PHEAT	W	3904.723	3983.279	3763.438	3172.931	1270.534
39	DEGEV	%	39.875	29.995	21.970	15.454	-0.336
40	DELTABT	VDC	3.372	5.362	7.482	9.374	13.292
41	EBATO	VDC	94.891	94.891	94.891	94.891	94.891
42	PLACTR	W	1052.948	1129.929	1118.815	1039.786	237.524
43	PLACOM	W	1027.881	1075.556	1024.790	904.215	-7.343

EVA DC MOTOR TEST WITH UNBUFFERED BATTERY/CHOPPER SOURCE

79-05-11   12:56:13   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	4003.605	3997.343	3999.450
2	TMOT	FT-#	4.994	8.555	13.399
3	TMOT	N-m	6.771	11.599	18.167
4	PABAT	W	4271.408	6089.028	8466.471
5	IBAT	ADC	47.359	68.886	98.437
6	PBAT	W	5805.059	7135.617	8453.959
7	IBAT	ARMS	64.341	80.688	98.364
8	DELTAMOT	PU	0.542	0.729	1.001
9	DELTAD2	PU	0.458	0.271	-0.001
10	DFM	VDC	1.025	0.773	1.095
11	PAMOT	W	3380.983	5327.442	8339.520
12	PTR	W	2838.715	4855.697	7608.851
13	PMOT	W	5470.425	6921.965	8277.678
14	EFFAMOT	%	83.961	91.145	91.238
15	WLAMT	W/N-m	80.092	40.670	40.220
16	EFFMOT	%	51.892	70.149	91.920
17	WLMOT	W/N-m	388.697	178.135	36.816
18	DEGM	%	38.195	23.036	-0.747
19	PLMOT	W	2631.710	2066.268	668.827
20	PLCTR	W	330.194	206.827	166.416
21	PACT	W	2.615	4.853	9.048
22	PCT	W	4.578	6.620	8.984
23	EMOT	VRMS	81.312	83.815	83.909
24	EFFCTR	%	94.235	97.006	97.915
25	WLCTR	W/N-m	48.769	17.831	9.161
26	PATH1	W	31.558	61.686	113.995
27	PAD2F	W	0.522	0.150	0.002
28	PTH1	W	74.721	100.071	113.076
29	PD2F	W	6.767	4.396	0.004
30	PLCOM	W	244.127	95.741	44.352
31	PLABT	W	187.200	396.203	800.801
32	PLBAT	W	345.510	543.583	799.603
33	PAEV	W	4458.608	6485.231	9267.272
34	EFFAEV	%	63.668	74.873	82.105
35	PEV	W	6150.569	7679.201	9253.563
36	EFFEV	%	46.154	63.232	82.226
37	WLEV	PU	1.167	0.581	0.216
38	PHEAT	W	2961.903	2273.096	835.243
39	DEGEV	%	27.509	15.548	-0.148
40	DELTABT	VDC	3.953	5.752	8.135
41	EBATO	VDC	94.144	94.144	94.144
42	PLACTR	W	887.911	756.537	117.033
43	PLACOM	W	853.216	689.847	-6.013

APPENDIX D2

PARAMETRIC TEST DATA, BUFFERED BATTERY MOTOR CHOPPER ENGINEERING DATA AND CALCULATED DATA FOR PULSED DC POWER OPERATION

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-05-23   11:28:23   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	MOTOR ROTOR SPEED
2	TMOT	FT-#	MOTOR SHAFT TORQUE
3	EBAT	VDC	BATTERY TERMINAL VOLTAGE, AVERAGE VALUE
4	EARM	VDC	MOTOR ARMATURE VOLTAGE, AVERAGE VALUE
5	EFM	VDC	MOTOR FIELD VOLTAGE, AVERAGE VALUE
6	IBAT'	ADC	BATTERY CURRENT, AVERAGE VALUE
7	IARM	ADC	MOTOR CURRENT, AVERAGE VALUE
8	ITH1	ADC	CURRENT IN THYRISTOR TH1(x), AVERAGE VALUE
9	ID2	ADC	CURRENT IN INVERSE BY-PASS DIODE D2(x), AVERAGE VALUE
10	VCT1	VDC	VOLTAGE DROP ACROSS CONTACTOR, AVERAGE VALUE
11	ETH1	VDC	VOLTAGE FROP DURING ON-CYCLE OF TH1(x), AVERAGE VALUE
12	EDF2	VDC	VOLTAGE DROP DURING ON-CYCLE OF D2(x), AVERAGE VALUE
15	PLAC4	W	POWER LOSS WITHIN COMMUTATING CAPACITOR C4, AVERAGE VALUE
16	MOTR TEMP	C	MOTOR FIELD WINDING TEMPERATURE
17	CONTROLR	HZ	DC CHOPPER PULSE REPETITION FREQUENCY
18	EBAT	VRMS	BATTERY TERMINAL VOLTAGE, R.M.S. VALUE
19	EARM	VRMS	MOTOR ARMATURE VOLTAGE, R.M.S. VALUE
20	EFM	VRMS	MOTOR FIELD VOLTAGE, R.M.S. VALUE
21	IBAT'	ARMS	BATTERY CURRENT, R.M.S. VALUE
22	IARM	ARMS	MOTOR CURRENT, R.M.S. VALUE
23	ITH1	ARMS	CURRENT IN THYRISTOR TH1, R.M.S. VALUE
24	ID2	ARMS	CURRENT IN INVERSE BY-PASS DIODE D2, R.M.S. VALUE
25	IC4	ARMS	CURRENT IN CAPACITOR C4, R.M.S. VALUE
26	ITH2	ARMS	CURRENT IN THYRISTOR TH2, R.M.S. VALUE
27	ID4	ARMS	CURRENT IN DIODE D4, R.M.S. VALUE
28	VCT1	VRMS	VOLTAGE DROP ACROSS CONTACTOR CT1, R.M.S. VALUE
29	ETH1	VRMS	VOLTAGE DROP DURING ON-CYCLE OF TH1(x), R.M.S. VALUE
30	EDF2	VRMS	VOLTAGE DROP DURING ON-CYCLE OF D2(x), R.M.S. VALUE
31	VC4	VRMS	CAPACITOR C4 VOLTAGE (x) DURING COMMUTATION, R.M.S. VALUE
34	PLC4	W	HEAT LOSS IN CAPACITOR C4
35	VINT	VRMS	VOLTAGE DROP ACROSS TH2 CURRENT SHUNT, R.M.S. VALUE
36	VINT	VDC	VOLTAGE DROP ACROSS TH2 CURRENT SHUNT, AVERAGE VALUE

(x) THIS DATA OBTAINED FROM EXTERNAL ADAPTOR CIRCUIT

Table D3. Nomenclature for Parametric Test Data, Buffered Battery.

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 1121; S.N.: 1276

79-06-22 15:02:01 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	681.312	840.842	1047.528	1307.566	1640.034	2051.383	2557.943	3200.238	3996.930
2	TMOT	FT-#	4.604	4.650	4.373	4.375	5.041	4.289	4.470	4.483	4.564
3	EBAT	VDC	103.073	102.828	102.772	102.722	102.595	102.564	102.505	102.495	102.422
4	EARM	VDC	10.692	13.521	16.390	20.433	27.031	32.512	40.476	51.623	64.377
5	EFM	VDC	0.027	1.062	0.311	0.537	0.290	0.523	0.853	0.563	0.116
6	IBAT'	ADC	12.850	15.735	17.996	21.051	27.394	29.687	35.613	42.084	47.807
7	IARM	ADC	49.627	52.537	50.303	51.580	58.582	53.836	54.672	55.682	55.135
8	ITH1	ADC	13.216	15.137	17.302	20.788	27.269	29.481	35.460	41.591	48.267
9	ID2	ADC	37.567	35.213	33.293	30.381	30.115	24.524	19.212	14.134	7.418
10	VCT1	VDC	0.054	0.052	0.050	0.051	0.056	0.052	0.052	0.055	0.054
11	ETH1	VDC	0.152	0.174	0.195	0.230	0.298	0.326	0.400	0.493	0.615
12	EDF2	VDC	0.562	0.488	0.424	0.374	0.307	0.250	0.202	0.154	0.103
13	PLABT	W	~~33.739~~	~~40.516~~	~~46.118~~	~~46.763~~	~~76.054~~	~~31.728~~	~~7.258~~	~~92.029~~	~~162.300~~
14	PLACOM	W	~~101.252~~	~~120.901~~	~~133.417~~	~~144.320~~	~~174.409~~	~~185.950~~	~~215.067~~	~~208.957~~	~~147.969~~
15	PLAC4	W	4.741	4.776	4.730	10.971	6.007	5.896	5.470	5.956	7.705
16	MOTR TEMP	C	38.728	39.609	40.301	41.276	42.392	43.837	45.608	47.372	49.668
17	CONTROLR	HZ	119.279	137.392	152.303	172.597	212.351	237.528	256.138	552.239	669.433
18	EBAT	VRMS	102.965	102.860	102.803	102.746	102.686	102.624	102.590	102.524	102.444
19	EARM	VRMS	11.452	14.163	17.139	21.242	27.941	33.428	41.528	52.646	65.561
20	EFM	VRMS	29.100	31.248	32.778	34.463	37.136	39.188	41.479	43.222	43.978
21	IBAT'	ARMS	44.092	48.505	52.457	56.870	65.376	65.917	69.668	73.480	72.156
22	IARM	ARMS	75.296	77.737	79.007	80.589	88.246	83.734	83.656	82.113	75.862
23	ITH1	ARMS	46.061	50.105	53.259	58.577	66.160	66.807	71.013	73.803	72.731
24	ID2	ARMS	63.441	64.710	63.804	63.924	65.536	58.003	51.861	42.777	30.653
25	IC4	ARMS	30.070	31.755	33.801	35.667	39.298	40.200	40.521	39.358	33.500
26	ITH2	ARMS	24.336	25.908	27.100	28.544	31.588	31.400	31.788	30.428	25.928
27	ID4	ARMS	8.448	8.084	7.704	7.264	7.212	7.436	7.916	8.412	8.484
28	VCT1	VRMS	0.081	0.083	0.084	0.086	0.094	0.089	0.091	0.089	0.081
29	ETH1	VRMS	0.644	0.685	0.722	0.771	0.837	0.922	1.005	1.069	1.144
30	EDF2	VRMS	0.625	0.593	0.560	0.532	0.503	0.454	0.398	0.353	0.290
31	VC4	VRMS	48.487	52.442	55.589	60.059	67.670	71.814	76.931	77.818	76.333
32	PLBT	W	~~249.681~~	~~270.430~~	~~293.626~~	~~351.673~~	~~386.465~~	~~448.051~~	~~563.431~~	~~1060.551~~	~~1483.031~~
33	PLCOM	W	~~1589.110~~	~~1718.429~~	~~1821.323~~	~~1959.866~~	~~2179.209~~	~~2229.690~~	~~2313.436~~	~~2299.040~~	~~2142.969~~
34	PLC4	W	29.943	32.026	33.684	49.388	72.883	73.462	74.189	70.701	60.397
35	VINT	VRMS	0.031	0.034	0.037	0.040	0.045	0.046	0.048	0.050	0.049
36	VINT	VDC	0.009	0.010	0.012	0.014	0.019	0.020	0.024	0.028	0.032

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 1121; S.N.: 1276

79-06-22   15:09:19   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	668.499	838.945	1046.758	1310.261	1636.235	2049.004	2561.809	3200.502	4003.467
2	TMOT	FT-#	8.629	8.962	8.351	8.867	8.920	8.700	8.763	8.751	8.736
3	EBAT	VDC	102.687	102.616	102.523	102.534	102.518	102.343	102.278	102.169	102.195
4	EARM	VDC	13.161	16.480	19.814	24.920	31.241	39.045	48.249	60.114	74.597
5	EFM	VDC	1.135	0.192	0.402	0.600	0.801	0.823	0.963	0.357	0.861
6	IBAT'	ADC	19.723	23.494	26.459	32.004	38.425	45.175	53.213	62.459	70.687
7	IARM	ADC	73.511	75.171	72.093	76.331	78.009	78.784	79.386	78.093	77.751
8	ITH1	ADC	19.094	22.286	25.989	31.311	38.200	45.319	53.601	62.318	70.653
9	ID2	ADC	53.536	51.063	46.823	44.308	39.642	33.257	24.992	16.787	6.958
10	VCT1	VDC	0.065	0.068	0.069	0.071	0.074	0.074	0.073	0.076	0.074
11	ETH1	VDC	0.191	0.230	0.262	0.328	0.388	0.462	0.549	0.670	0.812
12	EDF2	VDC	0.565	0.529	0.471	0.396	0.333	0.271	0.214	0.149	0.069
13	PLABT	W	~~78.797~~	~~86.732~~	~~94.537~~	~~115.243~~	~~133.163~~	~~143.697~~	~~119.809~~	~~24.216~~	~~206.272~~
14	PLACOM	W	~~123.877~~	~~142.650~~	~~164.531~~	~~191.526~~	~~219.314~~	~~249.143~~	~~267.132~~	~~251.066~~	~~154.[illegible]~~
15	PLAC4	W	-5.269	5.409	10.463	5.225	4.363	3.914	4.126	4.921	4.242
16	MOTR TEMP	C	42.487	43.459	44.735	46.056	47.795	49.224	51.512	53.627	56.495
17	CONTROLR	HZ	146.127	170.508	190.434	216.630	247.107	270.670	328.971	499.863	500.512
18	EBAT	VRMS	102.748	102.674	102.621	102.608	102.546	102.459	102.400	102.291	102.181
19	EARM	VRMS	13.876	17.078	20.600	25.962	32.086	39.857	49.424	61.085	75.401
20	EFM	VRMS	31.065	33.728	35.619	37.579	39.016	40.637	42.046	42.747	40.343
21	IBAT'	ARMS	57.191	62.346	66.880	75.165	82.687	89.468	93.219	95.907	92.998
22	IARM	ARMS	98.969	103.598	101.762	108.246	111.352	111.743	110.258	104.945	96.996
23	ITH1	ARMS	58.658	63.996	67.333	75.987	82.498	88.078	93.437	95.499	94.084
24	ID2	ARMS	84.467	83.903	82.775	83.944	80.278	73.672	63.300	48.719	31.076
25	IC4	ARMS	35.968	39.859	41.304	44.333	45.295	45.857	45.657	41.524	33.059
26	ITH2	ARMS	29.488	31.892	32.772	35.368	36.876	37.496	36.800	33.612	26.196
27	ID4	ARMS	7.764	7.352	7.244	7.444	7.988	8.744	9.272	9.296	8.844
28	VCT1	VRMS	0.097	0.100	0.102	0.110	0.113	0.114	0.113	0.110	0.099
29	ETH1	VRMS	0.683	0.750	0.791	0.830	0.867	0.928	0.999	1.067	1.164
30	EDF2	VRMS	0.621	0.606	0.579	0.547	0.504	0.449	0.400	0.335	0.260
31	VC4	VRMS	55.172	61.792	66.216	71.868	76.658	79.895	83.012	82.818	74.519
32	PLBT	W	~~341.623~~	~~368.022~~	~~389.159~~	~~428.468~~	~~457.168~~	~~466.742~~	~~452.879~~	~~695.968~~	~~1910.296~~
33	PLCOM	W	~~1861.069~~	~~2020.287~~	~~2122.403~~	~~2294.957~~	~~2969.971~~	~~3055.820~~	~~3067.038~~	~~2931.954~~	~~2090.369~~
34	PLC4	W	36.172	39.057	66.656	80.280	83.912	85.342	83.530	75.256	32.545
35	VINT	VRMS	0.040	0.044	0.046	0.053	0.057	0.061	0.064	0.065	0.063
36	VINT	VDC	0.012	0.015	0.017	0.021	0.025	0.030	0.035	0.042	0.047

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121B; S.N.: 1276

79-06-22 15:14:33 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	666.791	836.978	1048.966	1305.852	1636.340	2049.504	2558.438	3198.551	3997.680
2	TMOT	FT-#	13.130	13.221	13.600	13.106	13.115	13.433	12.856	13.655	13.707
3	EBAT	VDC	102.763	102.733	102.653	102.666	102.504	102.391	102.354	102.108	101.991
4	EARM	VDC	14.808	18.109	22.546	27.471	34.310	42.643	52.498	66.063	81.594
5	EFM	VDC	1.086	0.960	1.294	1.347	1.202	1.078	1.553	1.070	1.428
6	IBAT	ADC	25.775	29.988	36.096	41.528	49.743	60.762	69.534	84.445	96.085
7	IARM	ADC	95.271	95.500	99.387	96.596	98.211	101.023	97.978	104.123	102.830
8	ITH1	ADC	25.499	29.566	34.524	41.014	49.337	60.470	68.993	86.449	97.960
9	ID2	ADC	69.866	66.190	61.880	55.586	48.747	39.883	28.778	17.679	5.907
10	VCT1	VDC	0.089	0.089	0.093	0.092	0.094	0.097	0.095	0.100	0.096
11	ETH1	VDC	0.229	0.264	0.318	0.360	0.440	0.534	0.628	0.769	0.934
12	EDF2	VDC	0.540	0.514	0.479	0.415	0.350	0.275	0.205	0.126	0.045
13	PLABT	W	~~145.545~~	~~153.695~~	~~171.072~~	~~167.165~~	~~176.647~~	~~176.070~~	~~179.410~~	~~83.460~~	~~251.844~~
14	PLACOM	W	~~148.083~~	~~166.494~~	~~186.800~~	~~216.491~~	~~247.281~~	~~280.091~~	~~284.713~~	~~254.806~~	~~144.876~~
15	PLAC4	W	5.886	11.507	10.428	2.723	2.518	2.078	3.055	9.797	4.405
16	MOTR TEMP	C	52.559	53.023	53.951	55.479	56.702	58.589	60.561	63.346	65.686
17	CONTROLR	HZ	249.811	245.139	234.250	237.652	261.385	277.803	324.588	425.563	339.044
18	EBAT	VRMS	102.805	102.775	102.706	102.769	102.689	102.555	102.444	102.219	102.029
19	EARM	VRMS	15.688	19.060	23.438	28.432	35.229	43.638	53.375	66.868	82.659
20	EFM	VRMS	31.737	34.080	36.411	38.640	40.458	41.547	42.176	40.925	34.321
21	IBAT	ARMS	71.715	77.050	85.175	90.150	99.919	109.869	113.820	121.684	117.271
22	IARM	ARMS	123.559	125.942	129.985	129.126	132.818	136.353	131.548	131.939	120.747
23	ITH1	ARMS	73.237	78.191	85.369	90.626	99.300	109.795	113.515	122.311	118.651
24	ID2	ARMS	106.098	105.111	104.023	99.492	94.880	87.549	72.182	54.640	28.075
25	IC4	ARMS	42.266	45.817	48.966	50.310	52.517	52.778	48.726	44.453	30.511
26	ITH2	ARMS	34.580	36.696	39.192	40.680	42.324	43.056	40.620	36.240	24.900
27	ID4	ARMS	7.124	7.332	7.792	8.508	9.576	10.432	10.524	10.480	8.780
28	VCT1	VRMS	0.123	0.126	0.130	0.132	0.137	0.141	0.136	0.134	0.118
29	ETH1	VRMS	0.699	0.766	0.840	0.884	0.917	0.971	1.013	1.100	1.234
30	EDF2	VRMS	0.607	0.592	0.573	0.543	0.503	0.450	0.391	0.317	0.212
31	VC4	VRMS	61.961	68.630	76.555	82.216	87.130	89.647	89.565	86.556	73.481
32	PLBT	W	~~484.625~~	~~515.915~~	~~567.534~~	~~567.741~~	~~601.787~~	~~595.757~~	~~521.096~~	~~471.591~~	~~2061.796~~
33	PLCOM	W	~~2082.329~~	~~2233.991~~	~~2925.410~~	~~3068.440~~	~~3218.169~~	~~3320.378~~	~~3266.937~~	~~2961.090~~	~~1834.146~~
34	PLC4	W	42.013	61.353	84.862	91.859	95.568	96.261	90.412	45.136	30.745
35	VINT	VRMS	0.050	0.054	0.059	0.062	0.069	0.076	0.078	0.083	0.079
36	VINT	VDC	0.017	0.020	0.024	0.027	0.033	0.041	0.046	0.057	0.066

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22 15:19:34 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	665.133	838.193	1042.576	1304.090	1641.249	2048.242	2561.161	3195.856	3998.282
2	TMOT	FT-#	17.912	18.871	17.877	18.094	17.833	18.259	17.678	18.084	17.600
3	EBAT	VDC	103.053	103.046	102.948	102.881	102.705	102.538	102.272	102.075	101.654
4	EARM	VDC	16.308	20.240	24.230	29.878	36.948	45.952	56.534	70.040	86.189
5	EFM	VDC	1.251	1.043	1.766	1.550	1.613	1.929	1.209	1.216	1.455
6	IBAT'	ADC	33.502	41.807	45.655	53.069	64.643	78.037	89.752	107.885	116.549
7	IARM	ADC	121.053	124.981	120.303	120.655	120.565	122.956	122.108	126.390	122.024
8	ITH1	ADC	33.319	41.649	45.246	53.553	63.418	77.028	90.296	107.035	117.492
9	ID2	ADC	87.178	84.234	73.914	66.379	56.765	46.622	31.938	17.534	4.139
10	VCT1	VDC	0.115	0.119	0.116	0.118	0.118	0.123	0.124	0.126	0.119
11	ETH1	VDC	0.263	0.318	0.355	0.412	0.492	0.597	0.711	0.842	1.007
12	EDF2	VDC	0.532	0.503	0.469	0.418	0.347	0.272	0.191	0.110	0.027
13	PLAET	W	609.655	726.873	637.242	307.476	300.758	279.588	225.738	164.755	283.093
14	PLACOM	W	~~167.282~~	~~194.106~~	~~206.337~~	~~233.852~~	~~268.801~~	~~293.315~~	~~293.392~~	~~251.405~~	~~112.356~~
15	PLAC4	W	~~6.844~~	~~11.741~~	~~2.065~~	~~0.869~~	~~0.493~~	~~0.444~~	~~1.716~~	~~5.475~~	~~4.343~~
16	MOTR TEMP	C	57.808	59.255	61.133	62.206	63.869	66.025	68.421	71.323	73.852
17	CONTROLR	HZ	362.982	415.255	456.335	484.193	272.788	282.244	292.933	360.313	254.308
18	EBAT	VRMS	103.120	103.129	103.169	102.986	102.869	102.655	102.472	102.173	101.761
19	EARM	VRMS	17.464	21.403	25.299	30.861	37.996	46.932	57.293	70.681	87.069
20	EFM	VRMS	31.791	34.071	36.409	38.624	40.249	41.201	41.346	38.851	29.477
21	IBAT'	ARMS	89.127	98.715	100.922	108.866	119.317	132.175	138.976	143.690	131.714
22	IARM	ARMS	152.271	157.487	152.525	155.201	157.877	161.471	157.819	153.912	133.482
23	ITH1	ARMS	90.040	99.725	101.747	110.239	119.844	132.744	139.215	145.260	132.684
24	ID2	ARMS	129.077	129.581	120.417	116.470	109.521	99.572	81.064	57.278	24.490
25	IC4	ARMS	48.585	52.958	54.262	58.094	59.418	58.595	54.122	45.336	26.981
26	ITH2	ARMS	39.912	43.176	44.176	46.452	47.884	48.248	44.624	37.376	21.956
27	ID4	ARMS	7.144	8.012	8.544	9.656	10.808	11.888	12.112	11.128	8.084
28	VCT1	VRMS	0.152	0.162	0.157	0.162	0.166	0.172	0.169	0.162	0.135
29	ETH1	VRMS	0.726	0.797	0.858	0.939	0.990	1.042	1.075	1.140	1.235
30	EDF2	VRMS	0.608	0.590	0.570	0.545	0.503	0.447	0.381	0.298	0.182
31	VC4	VRMS	69.275	77.603	83.284	91.546	97.321	100.698	96.795	87.725	71.150
32	PLBT	W	~~860.356~~	~~975.407~~	~~896.495~~	~~939.410~~	~~963.220~~	~~954.662~~	~~698.351~~	~~438.166~~	~~2225.043~~
33	PLCOM	W	~~2261.444~~	~~2816.969~~	~~2995.211~~	~~3165.974~~	~~3287.970~~	~~3365.873~~	~~3332.842~~	~~2974.956~~	~~1585.542~~
34	PLC4	W	38.400	89.721	98.031	104.856	107.043	105.859	92.492	44.653	27.085
35	VINT	VRMS	0.062	0.069	0.070	0.076	0.083	0.091	0.095	0.098	0.089
36	VINT	VDC	0.023	0.027	0.029	0.035	0.042	0.052	0.061	0.072	0.078

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22 15:27:00 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	669.607	838.930	1043.032	1303.915	1634.162	2048.756	2562.791	3194.238	4002.818
2	TMOT	FT-#	22.130	22.693	22.234	22.130	23.066	22.297	22.650	22.179	19.741
3	EBAT	VDC	103.050	103.017	102.950	102.667	102.473	102.221	101.740	101.225	101.755
4	EARM	VDC	17.461	21.351	25.661	31.676	39.299	48.309	59.843	73.123	88.964
5	EFM	VDC	1.697	1.628	1.572	1.646	1.597	2.147	1.830	1.988	1.636
6	IBAT'	ADC	41.279	49.313	54.764	65.749	79.468	92.292	111.672	124.573	127.830
7	IARM	ADC	141.529	142.877	138.281	136.904	147.076	144.381	146.135	142.470	131.357
8	ITH1	ADC	40.671	48.993	54.610	65.032	80.627	94.310	112.822	127.123	128.520
9	ID2	ADC	99.586	93.695	83.718	76.290	64.581	50.729	33.670	17.036	3.200
10	VCT1	VDC	0.137	0.142	0.139	0.138	0.148	0.149	0.151	0.150	0.130
11	ETH1	VDC	0.298	0.343	0.390	0.460	0.556	0.655	0.783	0.912	1.047
12	EDF2	VDC	0.523	0.489	0.452	0.406	0.340	0.265	0.180	0.096	0.016
13	PLABT	W	~~998.743~~	~~1087.351~~	~~1035.345~~	~~1092.098~~	~~1183.654~~	~~1050.205~~	~~280.874~~	~~169.449~~	~~303.655~~
14	PLACOM	W	~~185.490~~	~~205.375~~	~~225.622~~	~~245.371~~	~~270.856~~	~~291.262~~	~~283.417~~	~~226.927~~	~~89.554~~
15	PLAC4	W	10.057	7.850	0.896	0.114	1.147	0.925	0.482	5.727	4.503
16	MOTR TEMP	C	63.118	65.255	67.292	69.480	71.726	74.700	78.545	81.549	85.086
17	CONTROLR	HZ	388.042	435.768	478.384	525.205	280.113	282.788	262.811	321.932	178.916
18	EBAT	VRMS	103.210	103.178	103.113	102.927	102.669	102.475	101.945	101.451	101.813
19	EARM	VRMS	18.808	22.678	26.905	32.788	40.452	49.272	60.633	73.903	89.626
20	EFM	VRMS	31.832	33.936	36.117	38.389	39.645	40.594	40.150	36.396	25.755
21	IBAT'	ARMS	103.851	111.955	116.910	124.994	142.185	150.570	163.008	162.125	140.801
22	IARM	ARMS	173.444	176.276	173.093	175.554	182.683	181.413	182.898	171.725	142.662
23	ITH1	ARMS	103.890	112.767	117.640	130.156	142.470	151.448	164.530	161.497	142.389
24	ID2	ARMS	144.041	142.370	134.555	130.366	123.076	107.628	86.824	55.627	22.094
25	IC4	ARMS	53.380	57.151	58.936	62.447	65.416	62.627	56.990	45.376	24.373
26	ITH2	ARMS	44.024	46.856	48.444	50.384	53.088	51.680	47.192	36.680	19.660
27	ID4	ARMS	7.708	8.624	9.432	10.436	12.040	12.940	13.272	11.440	7.496
28	VCT1	VRMS	0.178	0.185	0.184	0.188	0.198	0.198	0.198	0.182	0.143
29	ETH1	VRMS	0.752	0.821	0.885	0.968	1.047	1.097	1.140	1.198	1.221
30	EDF2	VRMS	0.606	0.587	0.565	0.541	0.499	0.442	0.371	0.274	0.161
31	VC4	VRMS	74.795	82.740	89.327	97.167	106.000	107.961	103.291	87.516	69.137
32	PLBT	W	~~1218.038~~	~~1303.968~~	~~1275.500~~	~~1328.113~~	~~1434.811~~	~~1302.667~~	~~1001.328~~	~~441.026~~	~~2324.861~~
33	PLCOM	W	~~2682.976~~	~~2850.935~~	~~2994.588~~	~~3161.923~~	~~3256.030~~	~~3299.656~~	~~3238.736~~	~~2322.206~~	~~1386.454~~
34	PLC4	W	74.785	98.287	107.387	113.532	117.674	109.691	54.581	43.876	24.195
35	VINT	VRMS	0.072	0.078	0.081	0.090	0.098	0.103	0.111	0.110	0.095
36	VINT	VDC	0.028	0.033	0.037	0.043	0.053	0.062	0.076	0.084	0.086

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112H; S.N.: 1276

79-06-22 15:34:05 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	669.639	837.397	1041.888	1310.158	1638.122	2043.506	2559.315	3199.500	4004.908
2	TMOT	FT-#	27.303	27.842	27.331	27.136	28.715	28.071	26.962	26.987	26.185
3	EBAT	VDC	103.060	102.904	102.927	102.605	102.226	101.777	101.388	100.713	100.379
4	EARM	VDC	18.650	22.653	27.307	33.479	41.653	50.816	61.970	76.192	95.973
5	EFM	VDC	1.760	1.897	1.721	2.149	2.172	1.748	2.271	2.404	2.100
6	IBAT'	ADC	52.419	61.173	67.117	78.695	98.442	113.971	130.635	150.669	158.572
7	IARM	ADC	165.913	166.028	163.737	161.721	170.792	167.294	165.676	166.528	159.614
8	ITH1	ADC	50.311	60.055	66.878	79.624	99.122	115.642	132.004	152.936	160.256
9	ID2	ADC	111.501	106.484	93.746	82.630	71.926	53.695	34.607	13.915	0.272
10	VCT1	VDC	0.163	0.160	0.159	0.158	0.168	0.166	0.162	0.163	0.152
11	ETH1	VDC	0.338	0.380	0.432	0.514	0.622	0.721	0.836	0.992	1.183
12	EDF2	VDC	0.508	0.476	0.437	0.387	0.327	0.250	0.170	0.070	0.023
13	PLABT	W	~~1432.434~~	~~1526.099~~	~~1477.403~~	~~1498.661~~	~~1626.682~~	~~1505.502~~	~~1020.251~~	~~145.939~~	~~204.707~~
14	PLACOM	W	~~196.089~~	~~224.304~~	~~245.241~~	~~260.018~~	~~275.412~~	~~278.819~~	~~268.114~~	~~199.120~~	~~1.725~~
15	PLAC4	W	10.431	0.272	0.724	1.512	2.553	3.189	7.419	5.899	4.575
16	MOTR TEMP	C	70.245	73.919	76.703	79.408	82.254	85.830	88.841	92.465	94.819
17	CONTROLR	HZ	412.925	459.530	500.083	541.714	284.984	280.396	252.498	214.956	1.000
18	EBAT	VRMS	103.337	103.225	103.077	102.886	102.495	102.141	101.549	100.746	100.403
19	EARM	VRMS	20.191	24.182	28.609	34.654	42.800	51.709	62.623	76.799	96.132
20	EFM	VRMS	31.814	33.758	35.822	37.767	38.950	39.651	39.098	33.840	4.561
21	IBAT'	ARMS	121.203	131.794	136.789	146.378	165.696	174.983	180.881	182.706	158.554
22	IARM	ARMS	197.742	201.629	197.566	198.699	208.387	206.609	200.066	190.496	159.596
23	ITH1	ARMS	122.048	132.360	137.011	147.181	166.855	176.359	182.506	185.013	160.405
24	ID2	ARMS	161.966	159.086	150.506	141.665	134.696	116.792	90.147	52.706	0.342
25	IC4	ARMS	57.993	62.427	64.553	67.462	70.511	67.723	59.658	42.026	0.221
26	ITH2	ARMS	48.524	51.504	52.884	54.996	57.444	55.664	48.880	35.036	0.028
27	ID4	ARMS	8.332	9.344	10.260	11.352	12.988	14.024	14.120	11.408	0.024
28	VCT1	VRMS	0.205	0.206	0.204	0.205	0.217	0.215	0.207	0.193	0.151
29	ETH1	VRMS	0.790	0.864	0.927	1.009	1.103	1.159	1.195	1.217	1.176
30	EDF2	VRMS	0.600	0.579	0.557	0.529	0.489	0.435	0.361	0.253	0.023
31	VC4	VRMS	81.125	89.222	95.709	103.920	113.097	115.108	107.188	86.862	36.449
32	PLBT	W	~~1572.798~~	~~1659.499~~	~~1637.140~~	~~1688.137~~	~~1822.768~~	~~1728.110~~	~~1241.329~~	~~375.731~~	~~31.966~~
33	PLCOM	W	~~2802.324~~	~~2963.894~~	~~3079.658~~	~~3210.067~~	~~3311.964~~	~~3263.353~~	~~3133.723~~	~~2152.691~~	~~2.820~~
34	PLC4	W	95.070	111.176	117.084	121.664	124.009	109.782	58.268	41.557	4.594
35	VINT	VRMS	0.083	0.091	0.094	0.101	0.114	0.119	0.123	0.124	0.107
36	VINT	VDC	0.034	0.041	0.045	0.053	0.066	0.076	0.086	0.100	0.107

'EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 1121; S.N.: 1276

79-06-22 15:39:33 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	666.336	840.394	1047.541	1301.841	1640.269	2049.063	2561.240	3204.340	3969.083
2	TMOT	FT-#	28.122	27.807	27.495	27.361	28.525	27.423	28.428	27.891	22.148
3	EBAT	VDC	98.091	98.032	97.843	97.500	97.157	96.789	96.068	96.233	96.531
4	EARM	VDC	18.633	22.601	27.333	33.233	41.683	50.809	63.094	77.214	92.418
5	EFM	VDC	1.958	1.966	1.543	1.877	2.329	1.978	2.001	1.948	1.755
6	IBAT'	ADC	56.754	65.073	73.871	85.730	105.606	120.406	146.201	162.891	148.326
7	IARM	ADC	176.563	175.415	174.909	173.534	179.411	173.634	177.981	175.325	149.131
8	ITH1	ADC	55.997	64.332	74.525	86.527	105.747	122.173	147.857	164.103	150.227
9	ID2	ADC	120.620	112.540	99.431	87.804	72.317	53.518	31.596	10.088	0.089
10	VCT1	VDC	0.174	0.204	0.214	0.220	0.221	0.215	0.221	0.230	0.199
11	ETH1	VDC	0.373	0.422	0.488	0.570	0.681	0.793	0.948	1.116	1.280
12	EDF2	VDC	0.532	0.491	0.449	0.400	0.332	0.259	0.160	0.058	0.022
13	PLABT	W	~~1432.631~~	~~1458.668~~	~~1482.129~~	~~1504.213~~	~~1570.747~~	~~1362.433~~	~~304.190~~	~~102.002~~	~~$$$$$$$$$~~
14	PLACOM	W	~~182.640~~	~~202.867~~	~~217.665~~	~~230.304~~	~~240.172~~	~~241.541~~	~~207.384~~	~~132.260~~	~~1.983~~
15	PLAC4	W	1.840	0.629	0.309	1.271	1.868	5.142	6.950	4.752	4.081
16	MOTR TEMP	C	32.763	38.393	43.198	46.808	51.651	55.849	60.264	64.733	66.365
17	CONTROLR	HZ	430.875	475.525	511.277	277.210	287.403	278.244	231.733	164.477	1.000
18	EBAT	VRMS	98.365	98.342	98.059	97.862	97.479	97.134	96.382	95.980	96.553
19	EARM	VRMS	19.904	23.786	28.398	34.296	42.560	51.658	63.733	77.755	92.501
20	EFM	VRMS	30.977	33.011	34.783	36.437	37.528	38.077	35.899	29.040	3.553
21	IBAT'	ARMS	127.361	134.924	142.326	152.215	169.046	176.528	192.837	187.039	148.404
22	IARM	ARMS	207.918	205.828	205.203	205.672	210.594	206.121	209.344	193.074	149.596
23	ITH1	ARMS	128.680	135.494	143.117	153.874	169.909	178.664	195.527	190.594	150.356
24	ID2	ARMS	169.418	162.127	154.111	145.189	133.125	113.106	84.951	43.341	0.282
25	IC4	ARMS	58.334	61.283	64.092	66.820	68.244	65.717	56.288	35.386	0.221
26	ITH2	ARMS	49.076	51.224	53.332	55.016	56.376	53.956	46.744	29.448	0.032
27	ID4	ARMS	8.508	9.364	10.340	11.444	12.876	13.912	14.156	10.344	0.036
28	VCT1	VRMS	0.214	0.245	0.258	0.258	0.261	0.259	0.264	0.259	0.196
29	ETH1	VRMS	0.846	0.926	0.996	1.073	1.165	1.232	1.286	1.311	1.275
30	EDF2	VRMS	0.632	0.608	0.581	0.550	0.504	0.448	0.358	0.233	0.023
31	VC4	VRMS	82.106	89.270	96.510	103.993	111.730	113.486	106.791	85.398	35.568
32	PLBT	W	~~1579.222~~	~~1623.857~~	~~1664.182~~	~~1713.832~~	~~1788.846~~	~~1596.380~~	~~1125.514~~	~~412.906~~	~~31.209~~
33	PLCOM	W	~~2831.771~~	~~2979.163~~	~~3114.558~~	~~3231.724~~	~~3301.058~~	~~3268.806~~	~~3034.163~~	~~1829.971~~	~~2.477~~
34	PLC4	W	106.324	113.956	118.392	121.855	117.622	62.733	55.497	35.904	4.097
35	VINT	VRMS	0.087	0.092	0.098	0.105	0.116	0.121	0.131	0.127	0.100
36	VINT	VDC	0.037	0.042	0.048	0.057	0.070	0.081	0.099	0.109	0.100

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112D; S.N.: 1276

79-06-22 15:44:57 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	52.146	55.668	59.939	52.234	56.536	55.014
2	TMOT	FT-#	3.684	8.274	13.148	17.259	21.756	26.847
3	EBAT	VDC	101.797	101.479	101.232	100.904	100.601	100.341
4	EARM	VDC	1.678	2.390	3.116	3.520	4.126	4.722
5	EFM	VDC	0.026	1.134	0.910	0.957	1.383	1.829
6	IBAT´	ADC	5.071	6.836	11.003	14.389	18.006	24.925
7	IARM	ADC	47.064	72.479	100.047	116.561	143.812	169.235
8	ITH1	ADC	3.888	5.922	10.666	12.379	17.632	23.427
9	ID2	ADC	42.298	64.945	87.893	106.684	129.099	146.297
10	VCT1	VDC	0.040	0.065	0.093	0.114	0.142	0.169
11	ETH1	VDC	0.061	0.080	0.103	0.107	0.132	0.161
12	EDF2	VDC	0.656	0.659	0.655	0.649	0.641	0.638
13	PLABT	W	~~23.069~~	~~53.051~~	~~110.398~~	~~234.567~~	~~646.062~~	~~1030.842~~
14	PLACOM	W	~~39.783~~	~~50.704~~	~~60.526~~	~~64.884~~	~~74.333~~	~~82.875~~
15	PLAC4	W	4.502	4.732	4.948	5.210	5.453	5.755
16	MOTR TEMP	C	39.824	39.681	40.586	41.752	44.074	47.701
17	CONTROLR	HZ	34.675	68.675	125.305	143.263	169.706	195.706
18	EBAT	VRMS	101.738	101.503	101.193	100.975	100.706	100.577
19	EARM	VRMS	2.510	3.396	4.382	4.992	5.925	6.827
20	EFM	VRMS	15.008	17.013	18.315	18.887	19.478	20.106
21	IBAT´	ARMS	23.771	34.985	47.683	57.211	70.852	84.814
22	IARM	ARMS	57.600	87.562	118.344	139.947	168.522	194.890
23	ITH1	ARMS	24.466	35.789	48.285	57.849	72.165	85.753
24	ID2	ARMS	53.552	81.305	110.166	130.386	155.622	177.897
25	IC4	ARMS	15.426	20.361	25.837	29.268	33.520	38.575
26	ITH2	ARMS	14.040	18.916	23.984	27.188	31.480	34.872
27	ID4	ARMS	6.120	8.332	10.052	10.568	10.184	8.504
28	VCT1	VRMS	0.055	0.083	0.116	0.139	0.174	0.201
29	ETH1	VRMS	0.299	0.345	0.393	0.419	0.457	0.495
30	EDF2	VRMS	0.668	0.675	0.677	0.677	0.678	0.676
31	VC4	VRMS	27.287	31.117	35.268	37.868	41.648	45.510
32	PLBT	W	~~122.871~~	~~186.581~~	~~323.429~~	~~491.898~~	~~811.162~~	~~1140.538~~
33	PLCOM	W	~~781.800~~	~~1042.730~~	~~1271.812~~	~~1371.029~~	~~1526.882~~	~~1699.997~~
34	PLC4	W	16.000	21.262	26.527	29.976	34.689	39.131
35	VINT	VRMS	0.017	0.024	0.033	0.039	0.049	0.058
36	VINT	VDC	0.003	0.005	0.007	0.009	0.012	0.016

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEC: 29 1755 112H; S.N.: 1276

79-06-22 15:48:57 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	102.372	103.588	98.295	99.656	98.005	96.949
2	TMOT	FT-#	4.706	9.095	12.832	17.457	21.516	27.450
3	EBAT	VDC	101.502	101.184	100.935	100.721	100.384	100.024
4	EARM	VDC	2.475	3.282	3.934	4.630	5.165	5.997
5	EFM	VDC	0.664	0.864	0.803	1.215	1.348	1.949
6	IBAT'	ADC	5.633	8.804	11.880	16.997	20.551	27.611
7	IARM	ADC	48.785	69.055	96.814	119.913	138.369	169.917
8	ITH1	ADC	4.727	8.023	11.408	15.137	20.018	27.155
9	ID2	ADC	43.827	63.514	84.546	103.638	118.055	143.894
10	VCT1	VDC	0.044	0.066	0.087	0.114	0.133	0.166
11	ETH1	VDC	0.061	0.088	0.107	0.126	0.150	0.180
12	EDF2	VDC	0.641	0.645	0.636	0.636	0.631	0.624
13	PLABT	W	~~25.245~~	~~56.916~~	~~96.945~~	~~250.499~~	~~607.401~~	~~1101.178~~
14	PLACOM	W	~~51.173~~	~~62.939~~	~~66.939~~	~~76.829~~	~~80.168~~	~~94.626~~
15	PLAC4	W	4.530	4.757	5.012	5.315	5.483	5.986
16	MOTR TEMP	C	40.444	40.253	40.729	42.559	46.197	49.996
17	CONTROLR	HZ	43.476	64.859	140.305	167.073	189.091	222.412
18	EBAT	VRMS	101.457	101.187	100.998	100.759	100.479	100.183
19	EARM	VRMS	3.270	4.161	4.982	5.345	6.729	7.853
20	EFM	VRMS	17.287	18.923	19.675	20.515	20.982	21.453
21	IBAT'	ARMS	27.663	37.452	48.284	60.962	72.116	90.270
22	IARM	ARMS	61.370	88.207	116.215	142.740	163.815	197.547
23	ITH1	ARMS	27.641	38.600	49.822	62.015	73.217	91.233
24	ID2	ARMS	56.654	81.748	106.541	130.991	149.761	177.695
25	IC4	ARMS	17.392	22.287	27.282	31.454	35.265	40.922
26	ITH2	ARMS	15.384	20.680	24.780	28.900	32.004	36.528
27	ID4	ARMS	6.860	8.588	9.928	10.164	9.560	7.348
28	VCT1	VRMS	0.060	0.086	0.113	0.139	0.162	0.196
29	ETH1	VRMS	0.341	0.385	0.420	0.455	0.485	0.532
30	EDF2	VRMS	0.658	0.664	0.666	0.667	0.665	0.666
31	VC4	VRMS	29.700	33.658	37.001	40.696	43.727	49.404
32	PLBT	W	~~139.051~~	~~203.940~~	~~322.007~~	~~544.719~~	~~793.051~~	~~1221.851~~
33	PLCOM	W	~~911.963~~	~~1153.680~~	~~1332.233~~	~~1487.042~~	~~1596.932~~	~~1811.554~~
34	PLC4	W	18.187	23.505	27.735	32.218	35.945	41.597
35	VINT	VRMS	0.019	0.027	0.034	0.043	0.050	0.062
36	VINT	VDC	0.003	0.005	0.007	0.011	0.013	0.018

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE
DC SERIES MOTOR, 10 HP, 3800 RPM
BALDOR ELECTRIC CO., ST. LOUIS, MO
SPEO: 29 1755 1121; S.N.: 1276

79-06-22 15:54:27 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	197.530	199.171	198.552	220.881	201.147	198.950
2	TMOT	FT-#	4.451	8.774	12.637	17.808	21.198	27.303
3	EBAT	VDC	101.244	100.883	100.608	100.282	100.112	99.768
4	EARM	VDC	3.685	4.966	5.775	6.666	7.450	8.220
5	EFM	VDC	0.164	0.766	1.107	1.306	1.721	2.063
6	IBAT'	ADC	6.385	10.485	14.038	19.661	23.520	32.579
7	IARM	ADC	46.180	72.056	93.666	121.585	148.338	171.540
8	ITH1	ADC	6.092	9.698	13.792	19.282	24.925	32.429
9	ID2	ADC	40.435	62.384	81.760	102.561	123.674	137.814
10	VCT1	VDC	0.042	0.066	0.088	0.114	0.141	0.168
11	ETH1	VDC	0.076	0.106	0.129	0.157	0.173	0.214
12	EDF2	VDC	0.625	0.622	0.617	0.613	0.605	0.598
13	PLABT	W	~~24.942~~	~~59.026~~	~~101.128~~	~~285.361~~	~~804.454~~	~~1150.070~~
14	PLACOM	W	~~61.779~~	~~73.963~~	~~78.277~~	~~93.002~~	~~97.164~~	~~112.666~~
15	PLAC4	W	4.440	4.849	5.088	5.563	5.933	6.334
16	MOTR TEMP	C	43.340	43.009	43.672	45.302	48.779	53.395
17	CONTROLR	HZ	56.218	83.495	178.039	209.978	235.674	264.743
18	EBAT	VRMS	101.216	100.901	100.639	100.363	100.159	99.968
19	EARM	VRMS	4.482	5.715	6.701	7.875	8.775	9.867
20	EFM	VRMS	19.347	21.624	22.473	23.101	23.308	23.827
21	IBAT'	ARMS	30.271	42.066	52.818	68.525	80.320	97.291
22	IARM	ARMS	63.069	90.961	115.825	145.865	172.233	197.371
23	ITH1	ARMS	31.301	43.170	54.149	69.577	82.700	97.622
24	ID2	ARMS	56.855	83.944	105.795	132.199	155.501	175.077
25	IC4	ARMS	19.599	25.195	30.010	35.727	40.601	44.975
26	ITH2	ARMS	17.336	22.584	26.832	31.520	35.592	38.808
27	ID4	ARMS	7.300	9.036	9.616	9.124	7.636	6.608
28	VCT1	VRMS	0.060	0.086	0.113	0.144	0.170	0.199
29	ETH1	VRMS	0.400	0.449	0.481	0.519	0.546	0.591
30	EDF2	VRMS	0.643	0.650	0.652	0.654	0.654	0.653
31	VC4	VRMS	32.894	37.663	41.309	45.603	50.346	55.491
32	PLBT	W	~~164.396~~	~~233.392~~	~~348.564~~	~~621.970~~	~~935.121~~	~~1284.618~~
33	PLCOM	W	~~1040.269~~	~~1299.919~~	~~1492.791~~	~~1676.829~~	~~1788.978~~	~~1950.370~~
34	PLC4	W	20.486	26.013	30.658	36.072	41.025	45.171
35	VINT	VRMS	0.021	0.029	0.037	0.047	0.055	0.066
36	VINT	VDC	0.004	0.007	0.009	0.013	0.017	0.022

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

79-05-23 11:29:01 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	MOTOR ROTOR SPEED
2	TMOT	FT-#	MOTOR SHAFT TORQUE
3	TMOT	N-m	MOTOR SHAFT TORQUE
4	PABAT	W	BATTERY POWER AVAILABLE AT TERMINAL, AVERAGE VALUE
5	IBAT	ADC	BATTERY CURRENT, AVERAGE VALUE
6	PBAT	W	BATTERY R.M.S. POWER AVAILABLE AT TERMINAL
7	IBAT	ARMS	BATTERY CURRENT, R.M.S. VALUE
8	DELTAMOT	PU	CHOPPER CONDUCTION DUTY CYCLE ΔMOT
9	DELTAD2	PU	DUTY CYCLE OF FREE WHEELING MODE ΔD2
10	DFM	VDC	MOTOR FIELD VOLTAGE, AVERAGE VALUE
11	PAMOT	W	AVERAGE POWER CONSUMPTION OF MOTOR
12	PTR	W	MOTOR POWER DELIVERED AT SHAFT
13	PMOT	W	R.M.S. POWER CONSUMPTION OF MOTOR
14	EFFAMOT	%	DC POWER TRANSFER EFFICIENCY OF MOTOR
15	WLAMT	W/N-m	MOTOR DC WATT-LOSS/TORQUE DELIVERED AT SHAFT
16	EFFMOT	%	MOTOR POWER TRANSFER EFFICIENCY BASED ON R.M.S. VALUES
17	WLMOT	W/N-m	MOTOR R.M.S. WATT-LOSS/TORQUE DELIVERED AT SHAFT
18	DEGM	%	MOTOR PERFORMANCE DEGRADATION IN PULSATING DC CURRENT MODE
19	PLMOT	W	HEAT LOSS IN MOTOR
20	PLCTR	W	HEAT LOSS IN DC CHOPPER PANEL
21	PACT	W	POWER LOSS ACROSS CONTACTOR C1
22	PCT	W	HEAT LOSS IN CONTACTOR C1
23	EMOT	VRMS	MOTOR VOLTAGE, R.M.S. VALUE
24	EFFCTR	%	POWER TRANSFER EFFICIENCY OF CONTROLLER
25	WLCTR	W/N-m	CONTROLLER WATT-LOSS/MOTOR TORQUE DELIVERED AT SHAFT
26	PATH1	W	AVERAGE POWER LOSS IN TH1
27	PAD2F	W	AVERAGE POWER LOSS IN D2
28	PTH1	W	HEAT DISSIPATION OF TH1
29	PD2F	W	HEAT DISSIPATION OF D2
30	PLCOM	W	HEAT DISSIPATION OF COMMUTATING CIRCUIT
31	PLABT	W	POWER LOSS WITHIN BATTERY WHEN DISCHARGING
32	PLBAT	W	HEAT DISSIPATION OF BATTERY WHEN DISCHARGING
33	PAEV	W	DC POWER FOR ELECTRIC DRIVE IN CONTINUOUS DC CURRENT MODE
34	EFFAEV	%	ELECTRIC DRIVE EFFICIENCY IN CONTINUOUS DC CURRENT MODE
35	PEV	W	R.M.S. POWER FOR ELECTRIC DRIVE IN PULSATING DC CURRENT MOD
36	EFFEV	%	ELECTRIC SYSTEM EFFICIENCY IN PULSATING DC CURRENT MODE
37	WLEV	PU	ELECTRIC SYSTEM WATT-LOSS/WATT DELIVERED AT MOTOR SHAFT
38	PHEAT	W	HEAT DISSIPATION OF ELECTRIC SYSTEM
39	DEGEV	%	SYSTEM PERFORMANCE DEGRADATION FOR PULSATING DC CURRENT MOD
40	DELTABT	VDC	VOLTAGE DROP WITHIN BATTERY, AVERAGE VALUE
41	EBATO	VDC	OPEN CIRCUIT BATTERY VOLTAGE, PEAK AMPLITUDE
42	PLACTR	W	POWER LOSS IN CHOPPER PANEL, AVERAGE VALUE
43	PLACOM	W	POWER LOSS IN COMMUTATING CIRCUIT, AVERAGE VALUE

Table D4. Nomenclature for Calculated Data, Parametric Chopper and Motor Test.

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

79-05-11 09:56:56 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	681.312	840.842	1047.528	1307.566	1640.034	2051.383	2557.943	3200.238	3996.930
2	TNOT	FT-#	4.604	4.650	4.373	4.375	5.041	4.289	4.470	4.483	4.564
3	TNOT	N-m	6.242	6.304	5.929	5.931	6.834	5.815	6.060	6.078	6.188
4	PABAT	W	1323.105	1616.352	1847.853	2160.602	2807.993	3042.437	3647.691	4310.065	4892.621
5	IBAT	ADC	12.837	15.719	17.980	21.033	27.370	29.664	35.585	42.051	47.769
6	PBAT	W	4534.999	4983.724	5386.756	5836.541	6704.870	6756.720	7138.783	7524.604	7383.773
7	IBAT	ARMS	44.044	48.452	52.399	56.806	65.295	65.840	69.586	73.394	72.076
8	DELTAMOT	PU	0.085	0.105	0.118	0.137	0.176	0.203	0.262	0.328	0.439
9	DELTAD2	PU	0.915	0.895	0.882	0.863	0.824	0.797	0.738	0.672	0.561
10	DFM	VDC	0.626	1.585	0.769	0.941	0.627	0.798	1.075	0.731	0.227
11	PAMOT	W	561.687	793.656	863.139	1102.456	1620.275	1793.289	2271.659	2915.148	3561.909
12	PTR	W	445.384	555.103	650.405	812.186	1173.735	1249.155	1623.351	2037.029	2590.251
13	PMOT	W	1268.250	1720.121	2112.295	2678.507	3669.064	4332.066	5313.670	6336.044	6741.737
14	EFFAMOT	%	79.294	69.943	75.353	73.671	72.440	69.657	71.461	69.877	72.721
15	WLAMT	W/N-m	18.631	37.842	35.881	48.939	65.341	93.579	106.980	144.471	157.015
16	EFFMOT	%	35.118	32.271	30.791	30.322	31.990	28.835	30.550	32.150	38.421
17	WLMOT	W/N-m	131.821	184.806	246.570	314.658	365.136	530.194	608.956	707.290	670.860
18	DEGM	%	55.712	53.860	59.137	58.841	55.840	58.604	57.249	53.991	47.166
19	PLMOT	W	822.865	1165.018	1461.890	1866.321	2495.329	3082.910	3690.319	4299.015	4151.486
20	PLCTR	W	3262.798	3259.267	3269.862	3153.011	3029.655	2418.857	1819.036	1182.414	636.474
21	PACT	W	2.670	2.724	2.507	2.609	3.302	2.779	2.853	3.043	2.950
22	PCT	W	6.132	6.489	6.619	6.958	8.278	7.460	7.595	7.276	6.155
23	EMOT	VRMS	17.172	22.353	26.950	33.394	41.663	51.809	63.578	77.205	88.890
24	EFFCTR	%	27.966	34.515	39.213	45.892	54.722	64.115	74.434	84.204	91.305
25	WLCTR	W/N-m	522.691	517.016	551.512	531.591	443.322	415.991	300.167	194.535	102.851
26	PATH1	W	2.006	2.634	3.379	4.774	8.127	9.612	14.185	20.495	29.697
27	PAD2F	W	21.094	17.168	14.127	11.351	9.237	6.140	3.886	2.178	0.764
28	PTH1	W	29.661	34.333	38.449	45.182	55.350	61.604	71.399	78.915	83.196
29	PD2F	W	39.620	38.392	35.716	34.036	32.945	26.322	20.645	15.106	8.881
30	PLCOM	W	3187.385	3180.054	3139.079	3066.836	2933.081	2323.471	1719.397	1081.116	538.242
31	PLABT	W	14.027	21.033	25.071	30.367	42.983	47.523	59.088	70.258	83.322
32	PLBAT	W	165.140	199.832	212.924	221.496	244.634	234.113	225.941	214.018	189.690
33	PAEV	W	1337.132	1637.385	1872.924	2190.970	2850.976	3089.961	3706.779	4380.323	4975.943
34	EFFAEV	%	33.309	33.902	34.727	37.070	41.170	40.426	43.794	46.504	52.055
35	PEV	W	4700.139	5183.556	5599.680	6058.037	6949.505	6990.833	7364.724	7738.621	7573.463
36	EFFEV	%	9.476	10.709	11.615	13.407	16.889	17.868	22.042	26.323	34.202
37	WLEV	PU	9.553	8.338	7.610	6.459	4.921	4.596	3.537	2.799	1.924
38	PHEAT	W	4085.663	4424.285	4731.753	5019.333	5524.984	5501.767	5509.355	5481.429	4787.959
39	DEGEV	%	71.551	68.412	66.553	63.834	58.976	55.800	49.668	43.397	34.298
40	DELTABT	VDC	1.093	1.338	1.394	1.444	1.570	1.602	1.660	1.671	1.744
41	EBATO	VDC	104.166	104.166	104.166	104.166	104.166	104.166	104.166	104.166	104.166
42	PLACTR	W	760.070	821.169	983.270	1056.571	1185.593	1247.235	1373.880	1392.475	1328.003
43	PLACOM	W	734.300	798.643	963.258	1037.837	1164.928	1228.704	1352.956	1366.758	1294.591

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

79-05-11 10:02:28 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	668.499	838.945	1046.758	1310.261	1636.235	2049.004	2561.809	3200.502	4003.467
2	TMOT	FT-#	8.629	8.962	8.351	8.867	8.920	8.700	8.763	8.751	8.736
3	TMOT	N-m	11.699	12.151	11.323	12.022	12.093	11.796	11.881	11.864	11.844
4	PABAT	W	2022.150	2407.463	2709.321	3277.501	3934.666	4618.151	5436.455	6374.392	7215.812
5	IBAT	ADC	19.692	23.461	26.427	31.965	38.380	45.124	53.154	62.390	70.609
6	PBAT	W	5867.920	6391.904	6853.523	7700.841	8466.131	9152.541	9530.734	9795.674	9489.139
7	IBAT	ARMS	57.110	62.254	66.785	75.051	82.559	89.329	93.074	95.763	92.866
8	DELTAMOT	PU	0.119	0.142	0.157	0.181	0.216	0.255	0.326	0.424	0.578
9	DELTAD2	PU	0.881	0.858	0.843	0.819	0.784	0.745	0.674	0.576	0.422
10	DFM	VDC	1.754	0.772	0.921	1.040	1.174	1.128	1.202	0.522	0.937
11	PAMOT	W	1096.453	1296.839	1494.830	1981.601	2528.596	3165.022	3925.666	4735.237	5872.815
12	PTR	W	819.014	1067.511	1241.199	1649.624	2072.224	2531.099	3187.320	3976.585	4965.638
13	PMOT	W	1964.591	2438.246	2958.730	3970.596	5139.940	6357.342	7565.450	8546.897	9139.789
14	EFFAMOT	%	74.697	82.316	83.033	83.247	81.952	79.971	81.192	83.979	84.553
15	WLAMT	W/N-m	23.715	18.874	22.400	27.614	37.737	53.742	62.148	63.943	76.594
16	EFFMOT	%	41.689	43.782	41.950	41.546	40.316	39.814	42.130	46.527	54.330
17	WLMOT	W/N-m	97.921	112.813	151.689	193.057	253.669	324.377	368.514	385.210	352.430
18	DEGM	%	44.189	46.813	49.477	50.093	50.805	50.215	48.111	44.597	35.745
19	PLMOT	W	1145.577	1370.735	1717.531	2320.972	3067.716	3826.243	4378.130	4570.312	4174.151
20	PLCTR	W	3896.612	3946.138	3887.249	3721.391	3316.477	2784.970	1954.741	1238.628	340.156
21	PACT	W	4.809	5.079	4.949	5.400	5.740	5.803	5.828	5.933	5.779
22	PCT	W	9.589	10.348	10.400	11.863	12.587	12.769	12.424	11.504	9.611
23	EMOT	VRMS	20.081	23.776	29.268	36.815	46.269	56.979	68.681	81.486	94.230
24	EFFCTR	%	33.480	38.146	43.171	51.561	60.712	69.460	79.380	87.252	96.318
25	WLCTR	W/N-m	333.074	324.771	343.314	309.544	274.239	236.101	164.533	104.398	28.720
26	PATH1	W	3.641	5.116	6.818	10.270	14.818	20.928	29.453	41.738	57.384
27	PAD2F	W	30.263	27.006	22.074	17.534	13.190	9.010	5.339	2.502	0.477
28	PTH1	W	40.091	48.023	53.282	63.060	71.502	81.729	93.299	101.911	109.526
29	PD2F	W	52.448	50.818	47.886	45.925	40.492	33.074	25.292	16.312	8.066
30	PLCOM	W	3794.484	3836.948	3775.681	3600.543	3191.895	2657.398	1823.727	1108.901	212.953
31	PLABT	W	7.343	10.421	14.188	16.794	20.798	32.335	41.571	55.545	61.089
32	PLBAT	W	61.758	73.376	90.614	92.580	96.234	126.719	127.459	130.859	105.673
33	PAEV	W	2029.493	2417.884	2723.509	3294.295	3955.464	4650.486	5478.026	6429.937	7276.901
34	EFFAEV	%	40.356	44.151	45.574	50.075	52.389	54.427	58.184	61.845	68.238
35	PEV	W	5929.679	6465.281	6944.137	7793.421	8562.366	9279.260	9658.193	9926.533	9594.812
36	EFFEV	%	13.812	16.511	17.874	21.167	24.202	27.277	33.001	40.060	51.753
37	WLEV	PU	6.240	5.056	4.595	3.724	3.132	2.666	2.030	1.496	0.932
38	PHEAT	W	5042.189	5316.873	5604.780	6042.362	6384.193	6611.213	6332.871	5808.940	4514.306
39	DEGEV	%	65.774	62.602	60.780	57.730	53.804	49.883	43.281	35.225	24.158
40	DELTABT	VDC	0.373	0.444	0.537	0.525	0.542	0.717	0.782	0.890	0.865
41	EBATO	VDC	103.060	103.060	103.060	103.060	103.060	103.060	103.060	103.060	103.060
42	PLACTR	W	922.751	1107.485	1211.496	1292.432	1402.233	1448.935	1506.142	1634.112	1337.433
43	PLACOM	W	884.038	1070.284	1177.655	1259.227	1368.485	1413.194	1465.521	1583.939	1273.793

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

79-05-11 10:08:57 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	666.791	836.978	1048.966	1305.852	1636.340	2049.504	2558.438	3198.551	3997.680
2	TMOT	FT-#	13.130	13.221	13.600	13.106	13.115	13.433	12.856	13.655	13.707
3	TMOT	N-m	17.802	17.925	18.439	17.769	17.781	18.213	17.431	18.514	18.583
4	PABAT	W	2643.434	3075.161	3699.056	4257.062	5091.464	6212.581	7107.367	8609.657	9785.112
5	IBAT	ADC	25.724	29.934	36.035	41.465	49.671	60.675	69.439	84.319	95.941
6	PBAT	W	7359.576	7904.757	8732.088	9247.939	10241.683	11246.078	11638.530	12414.720	11943.736
7	IBAT	ARMS	71.588	76.913	85.020	89.988	99.735	109.659	113.609	121.452	117.062
8	DELTAMOT	PU	0.129	0.151	0.180	0.212	0.248	0.306	0.374	0.482	0.672
9	DELTAD2	PU	0.871	0.849	0.820	0.788	0.752	0.694	0.626	0.518	0.328
10	DFM	VDC	1.696	1.541	1.835	1.818	1.601	1.393	1.787	1.214	1.480
11	PAMOT	W	1572.318	1876.503	2423.086	2829.119	3526.811	4448.637	5318.705	7005.091	8542.420
12	PTR	W	1243.094	1571.107	2025.566	2429.903	3047.075	3908.997	4670.212	6201.455	7779.920
13	PMOT	W	2622.730	3240.514	4123.447	5038.395	6435.399	8093.459	9579.839	11244.049	11778.005
14	EFFAMOT	%	79.061	83.725	83.594	85.889	86.397	87.870	87.807	88.528	91.074
15	WLAMT	W/N-m	18.494	17.038	21.558	22.468	26.980	29.630	37.204	43.407	41.031
16	EFFMOT	%	47.397	48.483	49.123	48.228	47.349	48.298	48.750	55.153	66.055
17	WLMOT	W/N-m	77.499	93.135	113.773	146.804	190.554	229.756	281.664	272.369	215.144
18	DEGM	%	40.050	42.092	41.236	43.849	45.197	45.034	44.480	37.700	27.471
19	PLMOT	W	1379.636	1669.407	2097.880	2608.492	3388.324	4184.462	4909.627	5042.595	3998.085
20	PLCTR	W	4726.378	4653.099	4596.386	4196.945	3792.375	3137.139	2043.459	1154.360	151.304
21	PACT	W	8.485	8.539	9.286	8.873	9.214	9.781	9.296	10.367	9.882
22	PCT	W	15.179	15.811	16.903	16.997	18.168	19.228	17.902	17.706	14.240
23	EMOT	VRMS	21.404	25.913	31.887	39.152	48.565	59.436	72.884	85.249	97.547
24	EFFCTR	%	35.637	40.994	47.222	54.481	62.835	71.967	82.311	90.570	98.612
25	WLCTR	W/N-m	265.496	259.594	249.273	236.201	213.278	172.251	117.232	62.351	8.142
26	PATH1	W	5.831	7.811	10.968	14.780	21.715	32.288	43.307	66.476	91.455
27	PAD2F	W	37.695	34.025	29.628	23.043	17.055	10.963	5.907	2.221	0.269
28	PTH1	W	51.182	59.865	71.744	80.138	91.086	106.664	114.968	134.504	146.384
29	PD2F	W	64.376	62.203	59.656	54.046	47.687	39.425	28.225	17.309	5.950
30	PLCOM	W	4595.641	4515.220	4448.083	4045.765	3635.433	2971.821	1882.364	984.841	-15.270
31	PLABT	W	4.848	6.563	10.773	11.853	22.235	34.024	41.542	71.153	92.146
32	PLBAT	W	37.545	43.330	59.969	55.824	89.647	111.135	111.199	147.622	137.185
33	PAEV	W	2648.282	3081.724	3709.828	4268.915	5113.699	6246.605	7148.909	8680.810	9877.259
34	EFFAEV	%	46.940	50.981	54.600	56.921	59.587	62.578	65.328	71.439	78.766
35	PEV	W	7397.121	7948.087	8792.056	9303.763	10331.329	11357.213	11749.730	12562.342	12080.921
36	EFFEV	%	16.805	19.767	23.039	26.117	29.494	34.419	39.747	49.365	64.398
37	WLEV	PU	4.951	4.059	3.341	2.829	2.391	1.905	1.516	1.026	0.553
38	PHEAT	W	6106.014	6322.506	6694.267	6805.437	7130.699	7321.601	6953.086	6196.955	4149.389
39	DEGEV	%	64.198	61.227	57.805	54.116	50.503	44.999	39.157	30.898	18.241
40	DELTABT	VDC	0.188	0.219	0.299	0.286	0.448	0.561	0.598	0.844	0.960
41	EBATO	VDC	102.952	102.952	102.952	102.952	102.952	102.952	102.952	102.952	102.952
42	PLACTR	W	1066.147	1193.556	1270.323	1422.335	1558.510	1756.911	1781.393	1595.319	1232.533
43	PLACOM	W	1014.135	1143.182	1220.441	1375.638	1510.526	1703.878	1722.883	1516.255	1130.927

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

79-05-11   10:14:35   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	665.133	838.193	1042.576	1304.090	1641.249	2048.242	2561.161	3195.856	3998.282
2	TMOT	FT-#	17.912	18.871	17.877	18.094	17.833	18.259	17.678	18.084	17.600
3	TMOT	N-m	24.285	25.585	24.237	24.532	24.178	24.756	23.968	24.518	23.862
4	PABAT	W	3443.895	4298.306	4690.575	5449.462	6627.649	7988.105	9163.481	10992.672	11826.374
5	IBAT	ADC	33.419	41.713	45.563	52.969	64.531	77.904	89.599	107.692	116.340
6	PBAT	W	9170.892	10157.932	10389.899	11187.384	12247.047	13537.687	14209.151	14648.360	13376.867
7	IBAT	ARMS	88.934	98.497	100.708	108.630	119.055	131.876	138.664	143.368	131.454
8	DELTAMOT	PU	0.141	0.179	0.205	0.238	0.294	0.349	0.418	0.564	0.783
9	DELTAD2	PU	0.859	0.821	0.795	0.762	0.706	0.651	0.582	0.436	0.217
10	DFM	VDC	1.871	1.631	2.310	2.035	2.017	2.249	1.432	1.344	1.486
11	PAMOT	W	2200.680	2733.356	3192.835	3850.438	4697.799	5926.604	7078.161	9022.244	10698.480
12	PTR	W	1691.558	2245.848	2646.259	3350.303	4155.653	5310.045	6428.421	8205.701	9991.171
13	PMOT	W	3458.741	4317.021	5110.442	6351.511	8039.208	10207.942	11815.590	13375.926	12802.353
14	EFFAMOT	%	76.865	82.164	82.881	87.011	88.460	89.597	90.820	90.950	93.389
15	WLAMT	W/N-m	20.965	19.054	22.551	20.387	22.423	24.906	27.109	33.304	29.642
16	EFFMOT	%	48.907	52.023	51.781	52.748	51.692	52.019	54.406	61.347	78.042
17	WLMOT	W/N-m	72.769	80.951	101.670	122.339	160.623	197.850	224.769	210.875	117.812
18	DEGM	%	36.373	36.684	37.523	39.378	41.564	41.941	40.095	32.549	16.433
19	PLMOT	W	1767.182	2071.173	2464.183	3001.209	3883.556	4897.897	5387.169	5170.224	2811.182
20	PLCTR	W	5696.271	5823.294	5262.427	4817.530	4187.974	3307.681	2371.224	1249.870	556.685
21	PACT	W	13.959	14.868	14.001	14.263	14.216	15.079	15.117	15.907	14.492
22	PCT	W	23.182	25.502	23.933	25.091	26.178	27.792	26.670	24.948	17.985
23	EMOT	VRMS	22.868	27.558	33.648	41.050	51.023	63.300	74.918	86.929	95.907
24	EFFCTR	%	37.714	42.499	49.187	56.774	65.642	75.404	83.155	91.313	95.705
25	WLCTR	W/N-m	234.561	227.602	217.123	196.377	173.214	133.614	98.935	50.978	23.330
26	PATH1	W	8.769	13.230	16.055	22.040	31.179	45.987	64.240	90.106	118.321
27	PAD2F	W	46.386	42.333	34.695	27.756	19.684	12.692	6.100	1.927	0.113
28	PTH1	W	65.356	79.527	87.332	103.528	118.656	138.339	149.664	165.590	163.826
29	PD2F	W	78.461	76.501	68.665	63.520	55.089	44.481	30.909	17.069	4.467
30	PLCOM	W	5529.272	5641.765	5082.497	4625.390	3988.051	3097.069	2163.982	1042.264	370.407
31	PLABT	W	1.011	1.575	6.176	10.745	24.448	42.470	72.697	108.603	166.326
32	PLBAT	W	7.161	8.781	30.174	45.193	83.214	121.700	174.114	192.477	212.348
33	PAEV	W	3444.906	4299.881	4696.751	5460.207	6652.097	8030.575	9236.178	11101.275	11992.700
34	EFFAEV	%	49.103	52.230	56.342	61.359	62.471	66.123	69.600	73.917	83.310
35	PEV	W	9178.053	10166.713	10420.073	11232.577	12330.261	13659.387	14383.265	14840.836	13589.216
36	EFFEV	%	18.430	22.090	25.396	29.827	33.703	38.875	44.694	55.291	73.523
37	WLEV	PU	4.426	3.527	2.938	2.353	1.967	1.572	1.237	0.809	0.360
38	PHEAT	W	7463.454	7894.467	7726.610	7818.739	8071.530	8205.579	7758.393	6420.094	3367.867
39	DEGEV	%	62.466	57.706	54.926	51.390	46.051	41.208	35.785	25.198	11.748
40	DELTABT	VDC	0.030	0.038	0.136	0.203	0.379	0.545	0.811	1.008	1.430
41	EBATO	VDC	103.083	103.083	103.083	103.083	103.083	103.083	103.083	103.083	103.083
42	PLACTR	W	1235.164	1556.094	1489.317	1590.152	1920.418	2050.827	2073.653	1956.584	1113.444
43	PLACOM	W	1166.050	1485.664	1424.566	1526.094	1855.340	1977.069	1988.196	1848.644	980.517

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

79-05-11   10:20:27   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	669.607	838.930	1043.032	1303.915	1634.162	2048.756	2562.791	3194.238	4002.818
2	TMOT	FT-#	22.130	22.693	22.234	22.130	23.066	22.297	22.650	22.179	19.741
3	TMOT	N-m	30.004	30.767	30.144	30.004	31.273	30.231	30.709	30.070	26.764
4	PABAT	W	4241.935	5067.258	5625.190	6736.375	8125.855	9414.877	11338.077	12583.716	12982.279
5	IBAT	ADC	41.164	49.189	54.640	65.614	79.298	92.103	111.442	124.315	127.583
6	PBAT	W	10692.306	11522.832	12025.911	12833.298	14560.818	15390.203	16574.045	16406.635	14305.057
7	IBAT	ARMS	103.598	111.679	116.628	124.683	141.823	150.185	162.578	161.720	140.503
8	DELTAMOT	PU	0.158	0.194	0.219	0.277	0.313	0.376	0.470	0.591	0.825
9	DELTAD2	PU	0.842	0.806	0.781	0.723	0.687	0.624	0.530	0.409	0.175
10	DFM	VDC	2.320	2.211	2.108	2.129	2.002	2.463	2.044	2.101	1.655
11	PAMOT	W	2799.619	3366.331	3839.864	4627.904	6074.473	7330.428	9043.788	10717.242	11903.400
12	PTR	W	2103.994	2703.049	3292.648	4097.015	5351.845	6486.068	8241.870	10058.681	11219.264
13	PMOT	W	4180.429	5101.487	5994.838	7588.876	9356.489	11560.504	14157.439	15565.422	14041.615
14	EFFAMOT	%	75.153	80.297	85.749	88.529	88.104	88.481	91.133	93.855	94.253
15	WLAMT	W/N-m	23.184	21.558	18.153	17.694	23.107	27.931	26.113	21.901	25.562
16	EFFMOT	%	50.330	52.986	54.925	53.987	57.199	56.105	58.216	64.622	79.900
17	WLMOT	W/N-m	69.205	77.955	89.642	116.381	128.056	167.857	192.632	183.132	105.452
18	DEGM	%	33.030	34.013	35.947	39.017	35.077	36.591	36.120	31.147	15.228
19	PLMOT	W	2076.435	2398.438	2702.189	3491.861	4004.644	5074.436	5915.569	5506.742	2822.350
20	PLCTR	W	6491.138	6399.147	6008.889	5220.265	5177.204	3801.505	2386.092	813.216	242.995
21	PACT	W	19.402	20.249	19.254	18.944	21.733	21.452	22.136	21.344	17.094
22	PCT	W	30.955	32.641	31.832	32.920	36.173	35.829	36.261	31.268	20.356
23	EMOT	VRMS	24.242	29.069	34.759	43.347	51.301	63.794	77.456	90.671	98.418
24	EFFCTR	%	39.098	44.273	49.849	59.134	64.258	75.116	85.419	94.873	98.158
25	WLCTR	W/N-m	216.342	207.988	199.338	173.988	165.551	125.750	77.700	27.044	9.079
26	PATH1	W	12.113	16.828	21.284	29.907	44.836	61.763	88.353	115.889	134.553
27	PAD2F	W	52.096	45.781	37.806	30.970	21.988	13.424	6.050	1.642	0.050
28	PTH1	W	78.144	92.533	104.143	126.016	149.135	166.064	187.612	193.482	173.857
29	PD2F	W	87.229	83.525	75.978	70.485	61.368	47.596	32.224	15.267	3.555
30	PLCOM	W	6294.811	6190.448	5796.936	4990.844	4930.528	3552.016	2129.995	573.200	45.226
31	PLABT	W	7.106	10.145	14.892	36.471	59.460	92.263	165.239	248.385	187.221
32	PLBAT	W	45.012	52.294	67.847	131.696	190.196	245.320	351.676	420.347	227.059
33	PAEV	W	4249.041	5077.403	5640.081	6772.846	8185.315	9507.140	11503.315	12832.102	13169.500
34	EFFAEV	%	49.517	53.237	58.379	60.492	65.383	68.223	71.648	78.387	85.191
35	PEV	W	10737.318	11575.126	12093.757	12964.994	14751.014	15635.523	16925.721	16826.983	14532.116
36	EFFEV	%	19.595	23.352	27.226	31.601	36.281	41.483	48.694	59.777	77.203
37	WLEV	PU	4.103	3.282	2.673	2.164	1.756	1.411	1.054	0.673	0.295
38	PHEAT	W	8567.573	8797.586	8711.078	8712.126	9181.848	8875.941	8301.661	6319.958	3065.345
39	DEGEV	%	60.427	56.135	53.364	47.761	44.510	39.195	32.036	23.741	9.377
40	DELTABT	VDC	0.173	0.206	0.273	0.556	0.750	1.002	1.483	1.998	1.467
41	EBATO	VDC	103.223	103.223	103.223	103.223	103.223	103.223	103.223	103.223	103.223
42	PLACTR	W	1431.243	1689.289	1774.061	2096.784	2037.092	2069.378	2277.060	1848.090	1061.876
43	PLACOM	W	1347.632	1606.430	1695.716	2016.963	1948.535	1972.738	2160.522	1709.214	910.179

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

79-05-11 10:26:09 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	669.639	837.397	1041.888	1310.158	1638.122	2043.506	2559.315	3199.500	4004.908
2	TMOT	FT-#	27.303	27.842	27.331	27.136	28.715	28.071	26.962	26.987	26.185
3	TMOT	N-m	37.017	37.749	37.056	36.791	38.932	38.059	36.555	36.588	35.501
4	PABAT	W	5385.586	6277.175	6889.908	8054.934	10038.713	11572.186	13213.629	15137.255	15879.049
5	IBAT	ADC	52.257	61.000	66.940	78.504	98.202	113.701	130.327	150.300	158.191
6	PBAT	W	12489.996	13566.319	14061.219	15018.620	16933.282	17820.476	18315.011	18354.798	15881.024
7	IBAT	ARMS	120.867	131.425	136.415	145.973	165.211	174.469	180.356	182.189	158.173
8	DELTAMOT	PU	0.187	0.215	0.241	0.289	0.353	0.425	0.522	0.681	1.000
9	DELTAD2	PU	0.813	0.785	0.759	0.711	0.647	0.575	0.478	0.319	-0.000
10	DFM	VDC	2.381	2.481	2.253	2.619	2.572	2.052	2.475	2.488	2.123
11	PAMOT	W	3489.153	4172.806	4840.037	5837.774	7553.150	8844.515	10676.951	13102.381	15657.511
12	PTR	W	2595.915	3310.365	4043.185	5047.818	6678.823	8144.800	9797.441	12259.370	14889.437
13	PMOT	W	4933.921	6129.258	7026.746	8793.038	11227.018	13477.061	15560.910	17143.100	15650.324
14	EFFAMOT	%	74.400	79.332	83.536	86.468	88.424	92.089	91.763	93.566	95.095
15	WLAMT	W/N-m	24.130	22.847	21.504	21.472	22.458	18.385	24.060	23.040	21.635
16	EFFMOT	%	52.614	54.009	57.540	57.407	59.489	60.435	62.962	71.512	95.138
17	WLMOT	W/N-m	63.160	74.675	80.515	101.798	116.823	140.104	157.666	133.478	21.433
18	DEGM	%	29.282	31.920	31.120	33.609	32.723	34.374	31.386	23.571	-0.046
19	PLMOT	W	2338.005	2818.893	2983.561	3745.220	4548.195	5332.262	5763.468	4883.730	760.887
20	PLCTR	W	7528.689	7407.582	7005.205	6194.655	5670.263	4306.178	2717.136	1176.191	204.934
21	PACT	W	27.006	26.599	26.053	25.626	28.730	27.793	26.824	27.201	24.208
22	PCT	W	40.509	41.604	40.207	40.775	45.166	44.436	41.512	36.678	24.081
23	EMOT	VRMS	25.065	30.522	35.667	44.352	53.959	65.293	77.822	90.004	98.086
24	EFFCTR	%	39.503	45.180	49.973	58.548	66.301	75.627	84.963	93.398	98.547
25	WLCTR	W/N-m	203.382	196.235	189.044	168.376	145.644	113.144	74.330	32.147	5.773
26	PATH1	W	16.995	22.816	28.917	40.912	61.619	83.423	110.396	151.690	189.557
27	PAD2F	W	56.633	50.695	40.978	32.000	23.541	13.450	5.871	0.981	0.006
28	PTH1	W	96.386	114.318	126.994	148.537	184.050	204.338	218.156	225.072	188.621
29	PD2F	W	97.124	92.182	83.812	74.877	65.845	50.785	32.574	13.344	0.008
30	PLCOM	W	7294.669	7159.478	6754.192	5930.466	5375.202	4006.620	2424.894	901.097	-7.776
31	PLABT	W	48.970	66.710	71.693	109.309	174.003	252.485	340.076	493.617	572.414
32	PLBAT	W	261.973	309.656	297.732	377.936	492.490	594.487	651.281	725.292	572.283
33	PAEV	W	5434.556	6343.885	6961.601	8164.244	10212.717	11824.671	13553.705	15630.872	16451.462
34	EFFAEV	%	47.767	52.182	58.078	61.828	65.397	68.880	72.286	78.430	90.505
35	PEV	W	12751.969	13875.975	14358.951	15396.556	17425.773	18414.964	18966.292	19080.090	16453.306
36	EFFEV	%	20.357	23.857	28.158	32.785	38.327	44.229	51.657	64.252	90.495
37	WLEV	PU	3.912	3.192	2.551	2.050	1.609	1.261	0.936	0.556	0.105
38	PHEAT	W	9866.694	10226.476	9988.767	9939.875	10218.458	9638.440	8480.604	6059.921	965.821
39	DEGEV	%	57.383	54.282	51.517	46.974	41.393	35.788	28.538	18.078	0.011
40	DELTABT	VDC	0.937	1.094	1.071	1.392	1.772	2.221	2.609	3.284	3.618
41	EBATO	VDC	103.997	103.997	103.997	103.997	103.997	103.997	103.997	103.997	103.997
42	PLACTR	W	1881.088	2088.472	2033.934	2200.634	2465.770	2706.728	2514.007	2009.109	195.793
43	PLACOM	W	1780.454	1988.362	1937.985	2102.096	2351.880	2582.062	2370.916	1829.237	-17.978

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

79-05-11 10:35:04 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	666.336	840.394	1047.541	1301.841	1640.269	2049.063	2561.240	3204.340	3969.083
2	TMOT	FT-#	28.122	27.807	27.495	27.361	28.525	27.423	28.428	27.891	22.148
3	TMOT	N-m	38.127	37.701	37.278	37.096	38.674	37.180	38.542	37.814	30.028
4	PABAT	W	5547.915	6359.276	7206.625	8335.897	10232.769	11623.921	14007.551	15633.178	14284.508
5	IBAT	ADC	56.559	64.870	73.655	85.497	105.322	120.096	145.809	162.452	147.978
6	PBAT	W	12489.451	13228.808	13914.529	14851.175	16427.169	17093.798	18526.112	17897.555	14295.223
7	IBAT	ARMS	126.970	134.518	141.900	151.756	168.520	175.982	192.215	186.472	148.056
8	DELTAMOT	PU	0.198	0.233	0.269	0.317	0.391	0.466	0.575	0.759	0.999
9	DELTAD2	PU	0.802	0.767	0.731	0.683	0.609	0.534	0.425	0.241	0.001
10	DFM	VDC	2.612	2.570	2.092	2.366	2.733	2.291	2.193	2.016	1.778
11	PAMOT	W	3750.922	4415.384	5146.714	6177.747	7968.841	9219.881	11619.791	13891.089	14047.541
12	PTR	W	2660.562	3318.036	4089.427	5057.483	6643.134	7978.186	10337.816	12689.377	12481.207
13	PMOT	W	5177.775	6058.416	7065.434	8659.971	10964.760	12979.918	16066.242	16843.488	14131.891
14	EFFAMOT	%	70.931	75.147	79.457	81.866	83.364	86.532	88.967	91.349	88.850
15	WLAMT	W/N-m	28.598	29.106	28.363	30.199	34.279	33.397	33.262	31.779	52.163
16	EFFMOT	%	51.384	54.767	57.879	59.401	60.586	61.466	64.345	75.337	88.319
17	WLMOT	W/N-m	66.021	72.687	79.834	97.111	111.746	134.529	148.628	109.855	54.972
18	DEGM	%	27.557	27.120	27.156	28.663	27.323	28.968	27.676	17.528	0.597
19	PLMOT	W	2517.213	2740.380	2976.008	3602.488	4321.626	5001.732	5728.426	4154.111	1650.684
20	PLCTR	W	7281.354	7139.623	6817.406	6157.836	5425.425	4076.341	2418.525	1017.016	140.694
21	PACT	W	30.664	35.771	37.403	38.128	39.621	37.367	39.413	40.393	29.661
22	PCT	W	44.467	50.407	53.012	53.135	54.999	53.284	55.254	49.912	29.379
23	EMOT	VRMS	25.017	29.535	34.521	42.193	52.137	63.035	76.791	87.251	94.490
24	EFFCTR	%	41.457	45.797	50.777	58.312	66.748	75.933	86.722	94.111	98.857
25	WLCTR	W/N-m	190.975	189.374	182.882	165.995	140.288	109.639	62.750	26.895	4.685
26	PATH1	W	20.887	27.129	36.389	49.294	71.976	96.824	140.214	183.220	192.285
27	PAD2F	W	64.147	55.290	44.655	35.147	23.980	13.864	5.048	0.582	0.002
28	PTH1	W	108.836	125.462	142.570	165.130	197.933	220.076	251.503	249.807	191.669
29	PD2F	W	107.153	98.557	89.614	79.856	67.087	50.691	30.389	10.080	0.006
30	PLCOM	W	7020.897	6865.196	6532.210	5859.715	5105.406	3752.289	2081.379	707.217	-80.360
31	PLABT	W	22.843	30.040	48.014	85.093	140.919	204.893	353.890	367.495	290.612
32	PLBAT	W	115.121	129.175	178.208	268.095	360.772	439.953	615.002	484.204	290.915
33	PAEV	W	5570.758	6389.316	7254.639	8420.991	10373.688	11828.814	14361.441	16000.673	14575.120
34	EFFAEV	%	47.759	51.931	56.370	60.058	64.038	67.447	71.983	79.305	85.634
35	PEV	W	12604.572	13357.983	14092.737	15119.270	16787.941	17533.750	19141.114	18381.759	14586.138
36	EFFEV	%	21.108	24.839	29.018	33.451	39.571	45.502	54.008	69.032	85.569
37	WLEV	PU	3.738	3.026	2.446	1.989	1.527	1.198	0.852	0.449	0.169
38	PHEAT	W	9798.567	9880.002	9793.414	9760.325	9747.051	9078.073	8146.951	5171.128	1791.378
39	DEGEV	%	55.804	52.169	48.522	44.303	38.208	32.537	24.971	12.954	0.076
40	DELTABT	VDC	0.404	0.463	0.652	0.995	1.338	1.706	2.427	2.262	1.964
41	EBATO	VDC	98.495	98.495	98.495	98.495	98.495	98.495	98.495	98.495	98.495
42	PLACTR	W	1779.481	1926.091	2041.501	2139.030	2241.918	2381.223	2360.730	1713.032	214.419
43	PLACOM	W	1663.784	1807.902	1923.053	2016.461	2106.341	2233.167	2176.054	1488.837	-7.529

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

79-05-11   10:42:46   MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	52.146	55.668	59.939	52.234	56.536	55.014
2	TMOT	FT-#	3.684	8.274	13.148	17.259	21.756	26.847
3	TMOT	N-m	4.995	11.218	17.826	23.400	29.497	36.398
4	PABAT	W	515.074	691.026	1108.606	1444.775	1800.496	2485.707
5	IBAT	ADC	5.060	6.810	10.951	14.318	17.897	24.773
6	PBAT	W	2416.148	3545.877	4815.690	5763.579	7115.595	8503.637
7	IBAT	ARMS	23.749	34.934	47.589	57.079	70.657	84.549
8	DELTAMOT	PU	0.045	0.038	0.053	0.063	0.064	0.086
9	DELTAD2	PU	0.955	0.962	0.947	0.937	0.936	0.914
10	DFM	VDC	0.725	1.858	1.653	1.714	2.154	2.614
11	PAMOT	W	113.125	307.921	477.166	609.967	903.110	1241.538
12	PTR	W	27.278	65.397	111.892	127.998	174.643	209.701
13	PMOT	W	158.866	434.355	650.512	857.817	1217.860	1622.777
14	EFFAMOT	%	24.113	21.238	23.449	20.984	19.338	16.890
15	WLAMT	W/N-m	17.187	21.620	20.491	20.597	24.696	28.348
16	EFFMOT	%	17.170	15.056	17.201	14.921	14.340	12.922
17	WLMOT	W/N-m	26.344	32.891	30.216	31.189	35.366	38.822
18	DEGM	%	28.792	29.108	26.648	28.893	25.845	23.493
19	PLMOT	W	131.589	368.959	538.620	729.819	1043.218	1413.076
20	PLCTR	W	2255.287	3106.963	4156.855	4894.080	5880.620	6857.777
21	PACT	W	1.906	4.676	9.309	13.282	20.400	28.641
22	PCT	W	3.152	7.286	13.670	19.398	29.259	39.218
23	EMOT	VRMS	2.942	5.132	5.642	6.283	7.359	8.448
24	EFFCTR	%	6.575	12.250	13.508	14.883	17.115	19.083
25	WLCTR	W/N-m	451.507	276.971	233.195	209.152	199.361	188.408
26	PATH1	W	0.235	0.473	1.098	1.328	2.319	3.766
27	PAD2F	W	27.759	42.799	57.569	69.187	82.803	93.270
28	PTH1	W	7.312	12.329	18.967	24.252	32.967	42.421
29	PD2F	W	35.778	54.861	74.600	88.294	105.476	120.287
30	PLCOM	W	2209.046	3032.487	4049.618	4762.136	5712.918	6655.851
31	PLABT	W	4.619	8.381	16.182	25.857	37.748	58.683
32	PLBAT	W	101.764	220.568	305.583	410.910	588.340	683.562
33	PAEV	W	519.694	699.407	1124.788	1470.632	1838.244	2544.390
34	EFFAEV	%	5.249	9.350	9.948	8.704	9.501	8.242
35	PEV	W	2517.912	3766.445	5121.274	6174.489	7703.935	9187.199
36	EFFEV	%	1.083	1.736	2.185	2.073	2.267	2.283
37	WLEV	PU	91.307	56.594	44.770	47.239	43.113	42.811
38	PHEAT	W	2386.876	3475.921	4695.475	5623.898	6923.837	8270.852
39	DEGEV	%	79.360	81.431	78.037	76.182	76.139	72.305
40	DELTABT	VDC	0.913	1.231	1.478	1.806	2.109	2.369
41	EBATO	VDC	102.710	102.710	102.710	102.710	102.710	102.710
42	PLACTR	W	400.807	380.398	626.259	827.777	886.644	1229.234
43	PLACOM	W	370.907	332.450	558.283	743.980	781.122	1103.557

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

79-05-11 10:47:21 MERADCOM, DRDME-EA, FT. BELVOIR, VA 22060

1	NTR	RPM	102.372	103.588	98.295	99.656	98.005	96.949
2	TMOT	FT-#	4.706	9.095	12.832	17.457	21.516	27.450
3	TMOT	N-m	6.381	12.331	17.398	23.669	29.171	37.217
4	PABAT	W	570.497	888.348	1194.125	1704.323	2052.830	2746.186
5	IBAT	ADC	5.621	8.780	11.831	16.921	20.450	27.455
6	PBAT	W	2803.891	3784.238	4867.325	6128.318	7227.131	9015.361
7	IBAT	ARMS	27.636	37.398	48.192	60.822	71.927	89.989
8	DELTAMOT	PU	0.041	0.055	0.060	0.077	0.081	0.093
9	DELTAD2	PU	0.959	0.945	0.940	0.923	0.919	0.907
10	DFM	VDC	1.349	1.573	1.525	1.955	2.098	2.719
11	PAMOT	W	186.581	335.291	528.481	789.605	1004.893	1480.988
12	PTR	W	68.409	133.765	179.091	247.013	299.400	377.857
13	PMOT	W	282.918	528.172	743.355	1097.886	1385.455	1975.508
14	EFFAMOT	%	36.665	39.895	33.888	31.283	29.794	25.514
15	WLAMT	W/N-m	18.519	16.343	20.082	22.925	24.184	29.641
16	EFFMOT	%	24.180	25.326	24.092	22.499	21.610	19.127
17	WLMOT	W/N-m	33.617	31.986	32.433	35.949	37.230	42.928
18	DEGM	%	34.051	36.519	28.906	28.079	27.468	25.033
19	PLMOT	W	214.509	394.407	564.264	850.872	1086.056	1597.651
20	PLCTR	W	2518.667	3251.346	4115.828	5018.099	5825.285	7015.757
21	PACT	W	2.150	4.573	8.456	13.692	18.392	28.139
22	PCT	W	3.654	7.625	13.134	19.819	26.458	38.767
23	EMOT	VRMS	4.811	6.202	6.553	7.838	8.598	10.133
24	EFFCTR	%	10.090	13.957	15.272	17.915	19.170	21.913
25	WLCTR	W/N-m	394.711	263.678	236.570	212.015	199.691	188.510
26	PATH1	W	0.288	0.706	1.220	1.911	3.010	4.885
27	PAD2F	W	28.100	40.987	53.809	65.894	74.513	89.854
28	PTH1	W	9.428	14.858	20.904	28.244	35.483	48.580
29	PD2F	W	37.306	54.248	70.975	87.377	99.657	118.340
30	PLCOM	W	2468.279	3174.615	4010.814	4882.659	5663.687	6810.070
31	PLABT	W	3.167	7.733	13.372	22.740	34.375	56.046
32	PLBAT	W	76.580	140.327	221.882	293.789	425.255	602.101
33	PAEV	W	573.665	896.081	1207.496	1727.062	2087.205	2802.232
34	EFFAEV	%	11.925	14.928	14.832	14.303	14.345	13.484
35	PEV	W	2880.471	3924.565	5089.207	6422.108	7652.385	9617.462
36	EFFEV	%	2.375	3.408	3.519	3.846	3.913	3.929
37	WLEV	PU	41.106	28.339	27.417	24.999	24.559	24.453
38	PHEAT	W	2733.176	3645.753	4680.092	5868.972	6911.341	8613.408
39	DEGEV	%	80.084	77.167	76.273	73.108	72.725	70.863
40	DELTABT	VDC	0.564	0.881	1.130	1.344	1.681	2.041
41	EBATO	VDC	102.065	102.065	102.065	102.065	102.065	102.065
42	PLACTR	W	382.686	550.584	660.780	907.243	1037.937	1250.052
43	PLACOM	W	352.147	504.318	597.295	825.745	942.022	1127.173

EVA DC MOTOR TEST WITH BUFFERED BATTERY/CHOPPER SOURCE

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1	NTR	RPM	197.530	199.171	198.552	220.881	201.147	198.950
2	TMOT	FT-#	4.451	8.774	12.637	17.808	21.198	27.303
3	TMOT	N-m	6.035	11.895	17.133	24.144	28.741	37.017
4	PABAT	W	645.325	1055.034	1407.651	1963.674	2342.814	3234.281
5	IBAT	ADC	6.374	10.458	13.991	19.582	23.402	32.418
6	PBAT	W	3060.885	4238.443	5305.839	6861.742	8023.009	9696.611
7	IBAT	ARMS	30.241	42.006	52.722	68.369	80.103	96.997
8	DELTAMOT	PU	0.044	0.062	0.070	0.082	0.085	0.112
9	DELTAD2	PU	0.956	0.938	0.930	0.918	0.915	0.888
10	DFM	VDC	0.830	1.451	1.807	2.022	2.450	2.801
11	PAMOT	W	208.489	462.402	710.234	1056.325	1468.487	1890.514
12	PTR	W	124.831	248.111	356.253	558.497	605.417	771.247
13	PMOT	W	371.389	719.970	1066.203	1499.289	1960.108	2480.795
14	EFFAMOT	%	59.874	53.657	50.160	52.872	41.227	40.796
15	WLAMT	W/N-m	13.863	18.015	20.660	20.619	30.030	30.236
16	EFFMOT	%	33.612	34.461	33.413	37.251	30.887	31.089
17	WLMOT	W/N-m	40.858	39.668	41.437	38.965	47.135	46.182
18	DEGM	%	43.862	35.775	33.387	29.545	25.081	23.794
19	PLMOT	W	246.558	471.859	709.950	940.792	1354.691	1709.548
20	PLCTR	W	2686.975	3513.316	4231.318	5349.166	6044.331	7191.158
21	PACT	W	1.917	4.782	8.254	13.831	20.984	28.755
22	PCT	W	3.771	7.830	13.071	20.942	29.326	39.372
23	EMOT	VRMS	6.166	8.101	9.377	10.423	11.494	12.680
24	EFFCTR	%	12.133	16.987	20.095	21.850	24.431	25.584
25	WLCTR	W/N-m	445.266	295.353	246.965	221.548	210.306	194.264
26	PATH1	W	0.462	1.024	1.785	3.025	4.317	6.954
27	PAD2F	W	25.267	38.802	50.478	62.823	74.784	82.477
28	PTH1	W	12.514	19.376	26.035	36.081	45.186	57.732
29	PD2F	W	36.558	54.575	69.020	86.458	101.671	114.338
30	PLCOM	W	2634.132	3431.535	4123.192	5205.685	5868.147	6979.717
31	PLABT	W	3.588	9.668	16.779	29.874	39.681	66.102
32	PLBAT	W	80.770	155.974	238.243	364.189	464.918	591.778
33	PAEV	W	648.913	1064.702	1424.430	1993.548	2382.495	3300.383
34	EFFAEV	%	19.237	23.303	25.010	28.015	25.411	23.368
35	PEV	W	3141.656	4394.418	5544.083	7225.931	8487.927	10288.389
36	EFFEV	%	3.973	5.646	6.426	7.729	7.133	7.496
37	WLEV	PU	24.167	16.711	14.562	11.938	13.020	12.340
38	PHEAT	W	2933.534	3985.175	4941.268	6289.958	7399.022	8900.706
39	DEGEV	%	79.345	75.771	74.307	72.411	71.931	67.921
40	DELTABT	VDC	0.563	0.924	1.199	1.526	1.696	2.039
41	EBATO	VDC	101.807	101.807	101.807	101.807	101.807	101.807
42	PLACTR	W	435.725	589.928	692.832	899.596	862.754	1328.182
43	PLACOM	W	408.080	545.319	632.314	819.917	762.669	1209.995

APPENDIX E

ON-BOARD BATTERY CHARGER

General Description. The EVA "Battery Marshall" charger is a solid state unit designed to operate from either 120 V RMS or 240 V RMS single phase utility power. The unit is primarily designed to recharge a 48-cell lead acid battery pack, typically sixteen EV-106 batteries, from a fully discharged to a fully recharged condition in eight to ten hours. In the low voltage mode, e.g.: 120 V RMS, the charging current is limited to typically 10 Ampere maximum, while in the high voltage mode, e.g.: 240 V RMS, up to 30 Ampere maximum is available to charge the battery. At its maximum charge rate the power transfer efficiency within the charger is typically 85% for the 120 V RMS connection, and 75% for the 240 V RMS operating mode. Correspondingly, the required power to sustain the maximum charge rate is one kilowatt @ 0.73 power factor for the 120 V RMS connection mode, and 3.6 kilowatt @ 0.46 power factor for the 240 V RMS connection mode. When adjusted properly, the battery charger will not overcharge the battery, but instead will slowly reduce the charge current to prevent excessive gassing. Charging will be terminated altogether when the battery reaches 2.5V/cell. (Ref. 7).

Electrical Characteristics. Circuit schematics for the battery charger are shown in Figures E1 through E5. The charger operates directly from a single phase power source without the benefit of an isolation transformer. A sensing circuit at the input monitors the line voltage in order to determine the required operating mode for the charger. Another monitor senses the power ground, and activates an interlock to disable the charger should a ground fault occur.

Both, the input as well as the output terminals of the charger are protected by 30 Ampere circuit breakers. Additional fuses protect the cooling fan, accessory receptacle and controls.

The charge rate is controlled by a full wave rectifier circuit which contains two thyristors. The gate trigger for either transistor is phase controlled by the set-reset mechanism of a saturable reactor, whereby the set time is a function of the trigger rate of the unijunction transistor voltage-controlled oscillator (Q3C). Transistor (Q3C), shown in Figure E4, in turn is manipulated by a current and voltage sensor circuit. Five adjustments make it possible to adjust trickle current, taper point voltage, maximum charge current for 120 V RMS operation, maximum current for 240 V RMS operation, and final point voltage cut-off. Because the charger fails to provide line isolation by virtue of an isolation transformer and/or a smoothing reactor, charge and line currents will exhibit a comparatively large peak/average amplitude ratio. This may burden the utility line unduly.

Lack of input/output isolation by virtue of an isolation transformer can create a grounding problem accompanied by a possible hazard to maintenance personnel. In order to minimize this hazard only floating type instrumentation is recommended for measurement of output parameters of the charger. In the event of a power failure in the utility line, the batteries when fully charged, emit a typically 1.5 mA current amplitude into the line through the charger. The measured impedance for this operating condition with the charger output open ended is typically 70,000 ohm.

Variation of line voltage causes a two percent change in output voltage in the 240 V RMS operating mode. However, in the low voltage or 120 V RMS mode, output current may change as much as 40% with a 10 volt change in line voltage. The charger contains one 0-30 Ampere meter. The accuracy of the meter varied from (-) 1% at 3 Amperes to (-) 12% at 25 Amperes. Preferteably, this meter should not be used to adjust the charge current rates. The five charger adjustments – trickle, taper, 120 V RMS line, 240 V RMS line, and final point – are screwdriver adjustments that are accessible through grommeted holes in the top of the charger case. It is recommended to use external instrumentation to make adjustments, and to maintain proper operation of the charger. The charge rate is controlled by a full wave rectifier circuit which contains two thyristors. Gate triggering is provided by a conventional saturable reactor set-reset trigger circuit, whereby the phase delay is manipulated by a current and voltage sensing unijunction transistor voltage-controlled-oscillator. (Ref 7).

Slope Characteristics. To determine the charge characteristics of the battery charging system, a battery pack consisting of sixteen EV-106 batteries was used as a load. Attempts were made to obtain the parameters of the charger with only a resistive load; however, the output characteristics were too unstable to obtain meaningful data. The circuit indicated in Figure E6 was used to obtain the input-output characteristics of the charger. The input source for the 115/120 voltage connection was a 30-ampere autotransformer across a 120-VAC line. The input for the 240-volt connection was obtained from a 15 kW Engine Generator. The 5 kW variable load was used to discharge the battery pack from full charge to 1.7 volts per cell following each charge cycle. Prior to the charge rate tests, the charger adjustments were made as follows:

a. Trickle current – 3 amperes.
b. Taper-point voltage – 110 volts.
c. 120-volt maximum current – 15 amperes.
d. 240-volt maximum current – 25 amperes.
e. Final-point voltage – 120 volts.

The battery pack was cycled from discharge to charge several times at the different voltage connections to obtain the input-output parameters as a function of time. The slope characteristics including voltage and current versus time and voltage versus current for the charger at three different input voltages are illustrated in Figures E7 through E12.

The tests on the charger were performed only at ambient temperatures of 72–75°F and 85–92°F. The output of the charger appeared to be stable and comparable at these ranges. Tests at the temperature extremes were not performed. (Ref 7).

Environmental Characteristics. The Electromagnetic Interference (EMI) tests were performed on the battery charger utilizing the procedures outlined in MIL-STD-462. The tests were conducted with the charger installed in an EVA No. 1 Metro Sedan. The radiated EMI was measured with the trunk lid in both the open and closed positions. The tests were performed using the 120-volt connection and a charger output of 10 amperes. The tests indicated that the charger radiates EMI in excess of the limits specified in MIL-STD-461A (REQ2, Figure 13) in the entire frequency range below 8 Megahertz. Figure E13, shows the radiated EMI from the charger to the MIL-STD-461A limits. Two additional limits, used for engine-generators, are also indicated on the graph.

The audio sound levels emanating from the charger are relatively low as indicated on Figure E14. The tests were performed in a sound chamber with the sensing microphone at a distance of 40 inches from the charger and 4 inches above the charger. Measurements were made on all four sides of the charger while the unit was operated on the 120-volt connection with an output of 10 amperes. The "db" values indicated on Figure E14, are the average of the four readings taken in each octave band. (Ref 7).

Maintenance. The EVA Corporation Battery Charger should require very little maintenance if afforded the proper care and if it is not abused; however, the unit should be subjected to a periodic preventive maintenance inspection to insure long service. This maintenance should include removing dust and dirt from all components including the printed circuit boards, cleaning exposed relay contacts, cleaning and lubricating the cooling fan, and readjusting the charge rate control potentiometers. This preventive maintenance should be performed at six-month intervals.

Repair to the charger could be quite difficult and should be attempted only by electronics technicians experienced in voltage regulator and control circuitry utilizing solid state components. The replacement of components within the charger, once a problem has been isolated, could also pose difficulties, especially on the printed circuit boards where all components are soldered directly to the board. Thus, the battery charger can be repaired only with some difficulty.

Recommendations. It is recommended that the control adjustments of the battery charger be adjusted only with external instrumentation with at least 1% accuracy. Since the charger characteristics are governed by these adjustments, the single ammeter on the charger is inadequate for this purpose and should only be used as an indicator that the charger is working.

The Electromagnetic Interference radiation from the charger should be suppressed by either filtering or shielding. Since the charger is designed for use primarily in residential environment, the charger would probably interfere with radio and television reception. Although the conducted interference tests were not performed because of the high radiated figure, the conducted noise would most likely compound the interference problems.

Because of the method of operation of the charger, isolation of the output from the input power line would require a redesign of the charger. It is, therefore, recommended that the output lines of the charger be thoroughly insulated and be insulated against possible contact with power ground. Any test instrumentation used in or around the charger output circuit must be isolated from power ground. Otherwise, damage could result to both the charger as well as to the instruments.

If the charger is used on a vehicle or battery pack that becomes greater than 50% discharged on a daily basis, the high input voltage range (230/240) should be used. If the discharge is less than 50%, the 114/120 range would be more efficient and should be sufficient to restore the battery to full charge overnight.

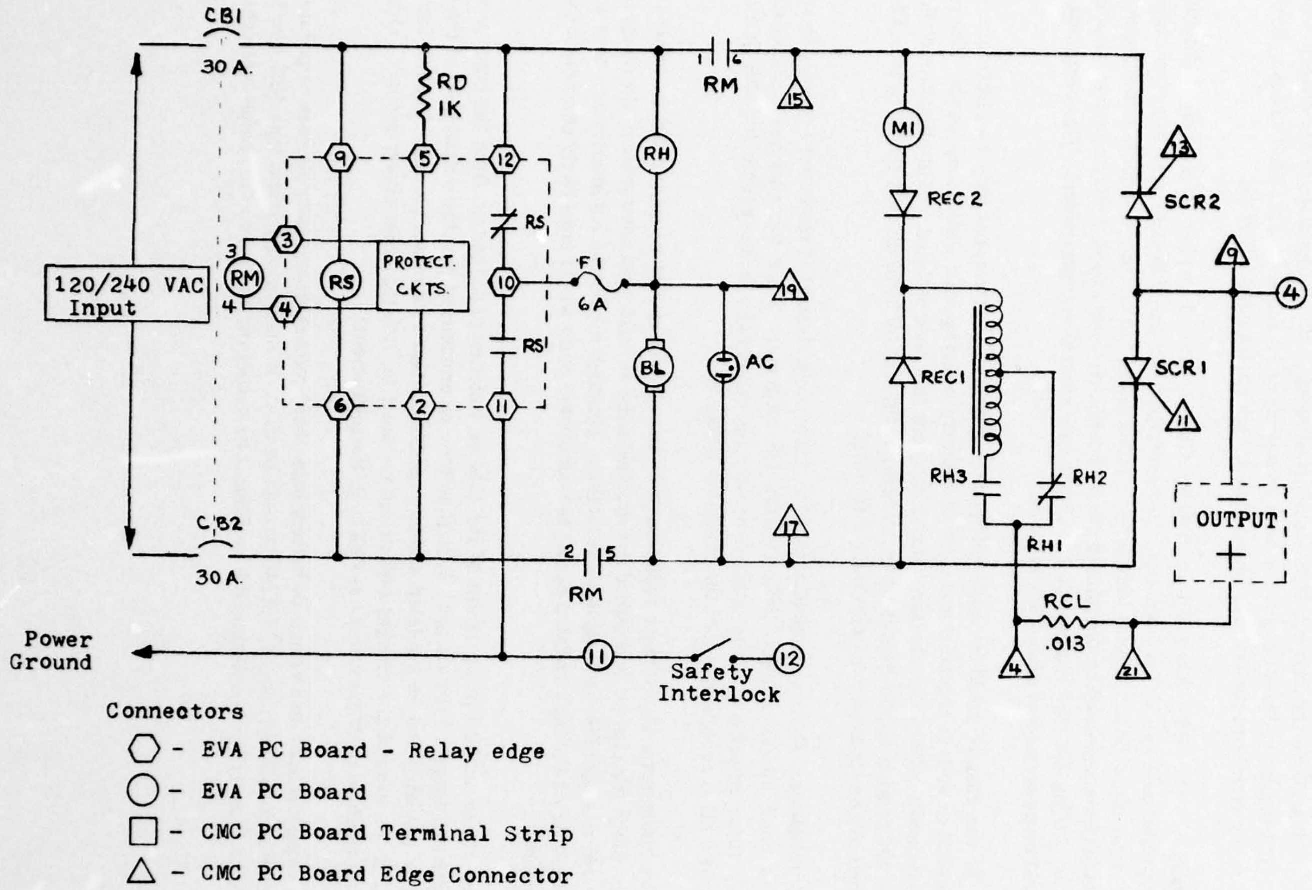


Figure E1. Main Input-Output Circuit (Components on PC Boards).

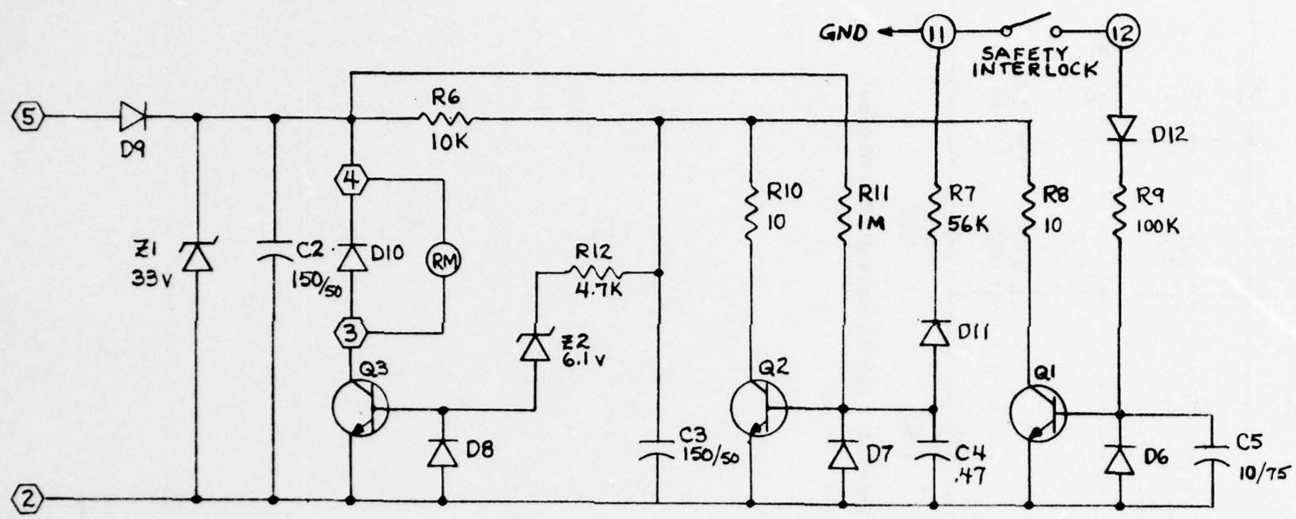


Figure E2. Ground Detector Circuit (On EVA PC Board).

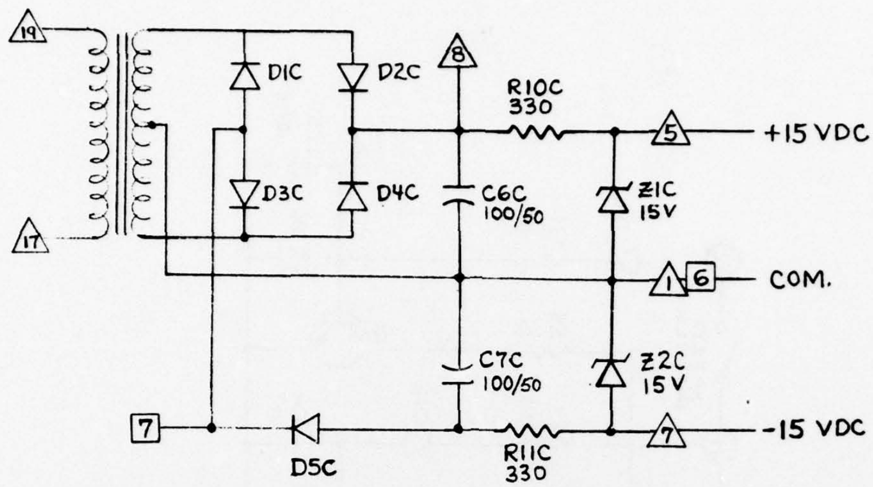
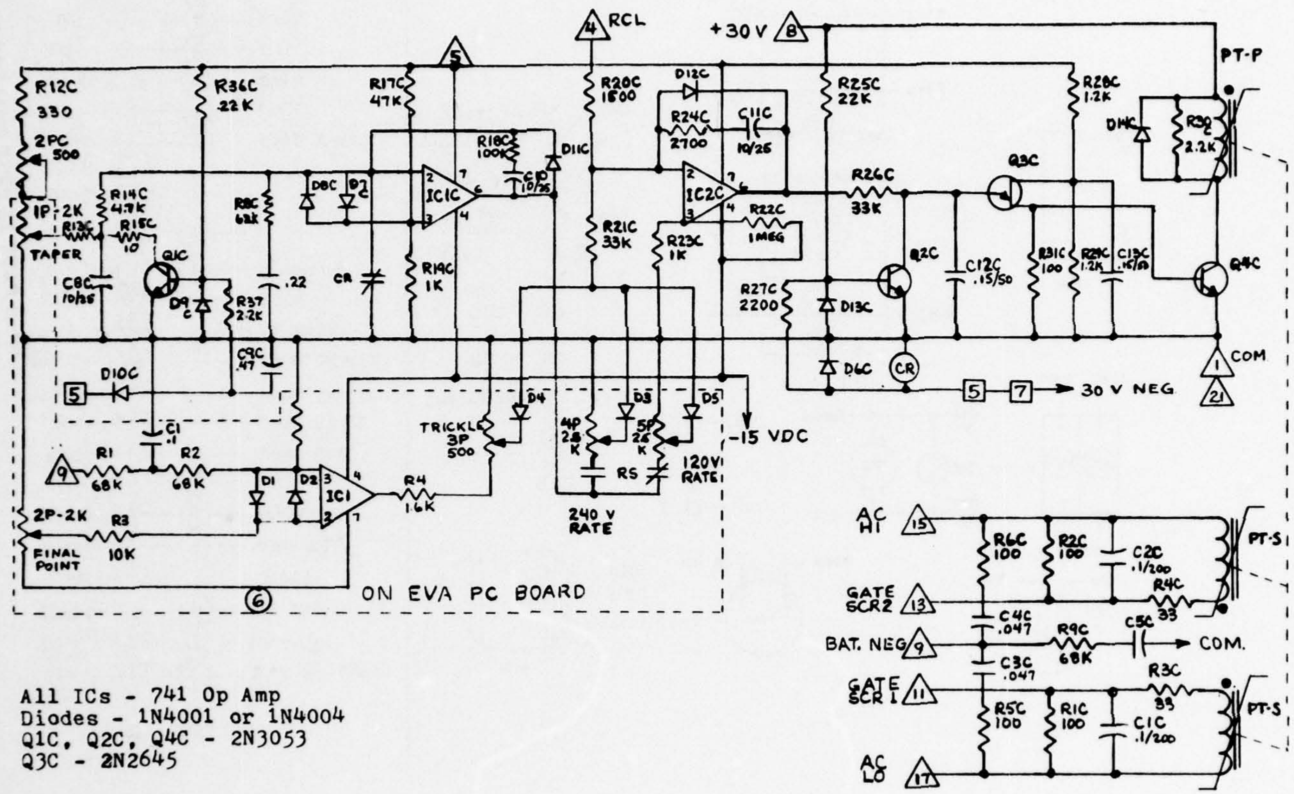


Figure E3. ± 15 V DC Supply (On CMC PC Board).



All ICs - 741 Op Amp
Diodes - 1N4001 or 1N4004
Q1C, Q2C, Q4C - 2N3053
Q3C - 2N2645

Figure E4. Battery Charger Control Circuit.

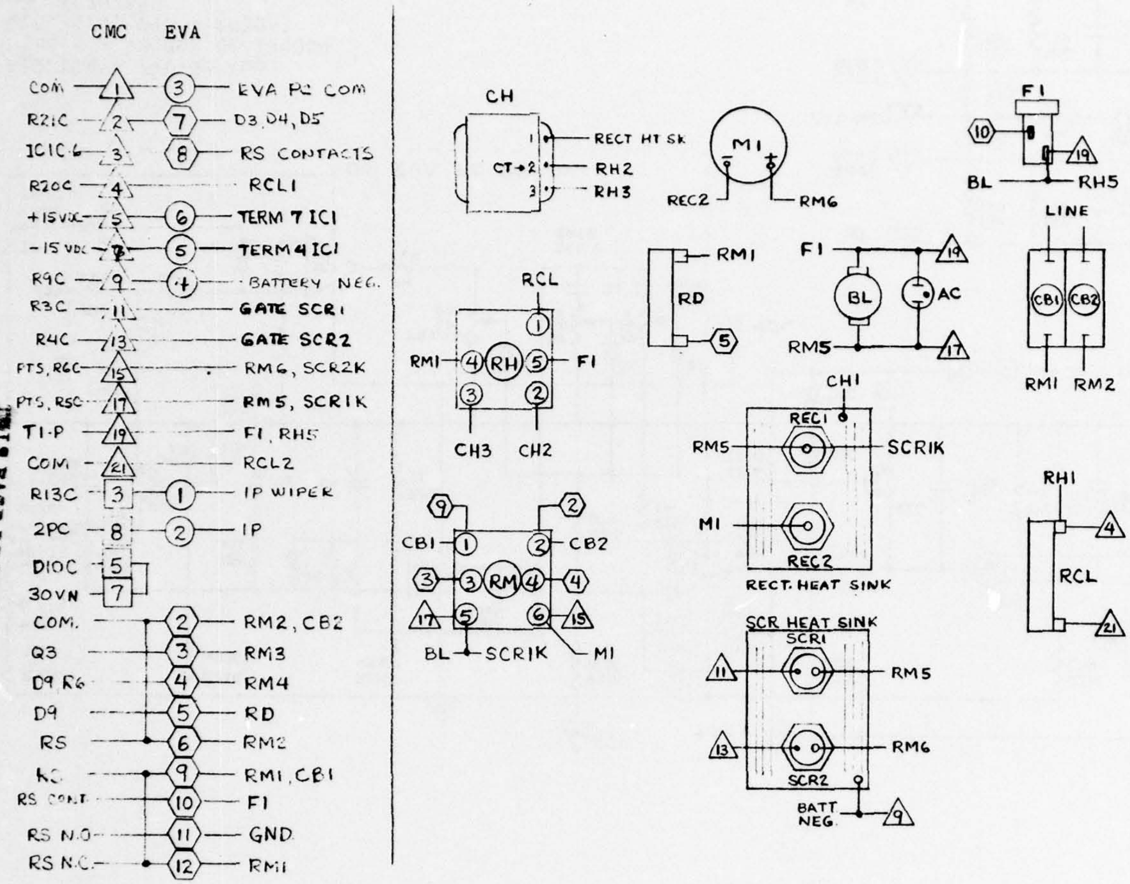
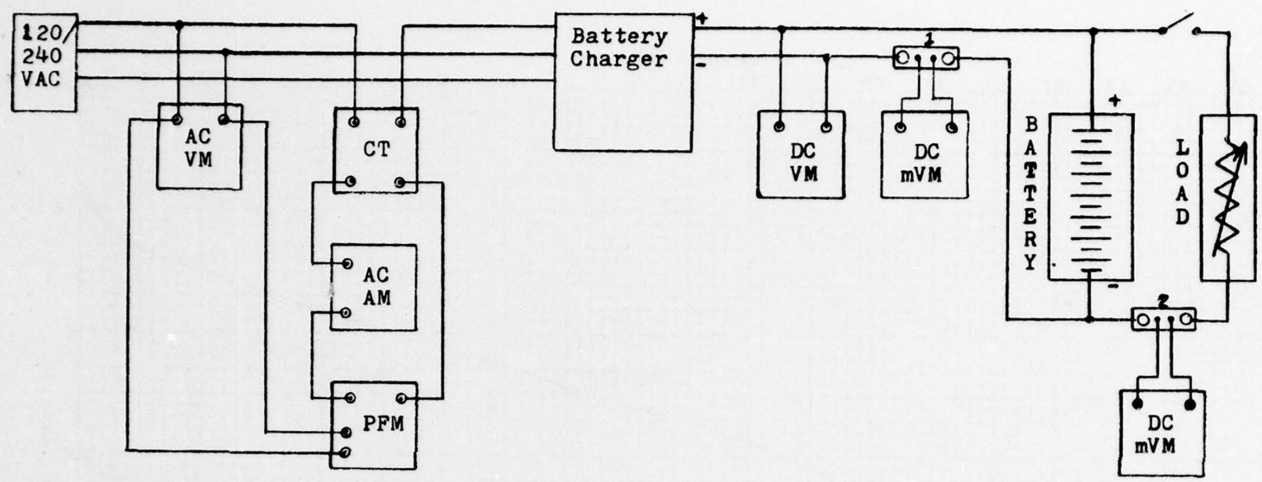


Figure E5. Connector and Component Wiring Schematic.



Instruments:

ACVM - A C Voltmeter, Weston 904, ID #1208
ACAM - A C Ammeter, Weston 904, ID # 0654
CT - Current Transformer, Weston 461, S/N 22167
PFM - Power Factor Meter, Weston 338, ID # 0168
DCVM - D C Voltmeter, Weston 901, ID # 0308
DCmVM - D C Millivoltmeter, Weston 931, ID # 0541 & 1246
Shunt #1 - 20 Amp/50 mv, ID # 16591
Shunt #2 - 100 Amp/50 mv, ID #16592
Battery - Sixteen EV106 Batteries in series
Load - 5KW resistive load, variable

Other instruments:

Digital Multimeter, Keithley 167, ID # 18374
Digital Multimeter, Keithley 168, ID # 22509
Storage Oscilloscope, Tektronix 549, ID #9686 .

Figure E6. Instrumentation to Determine Charge Rate Curves.

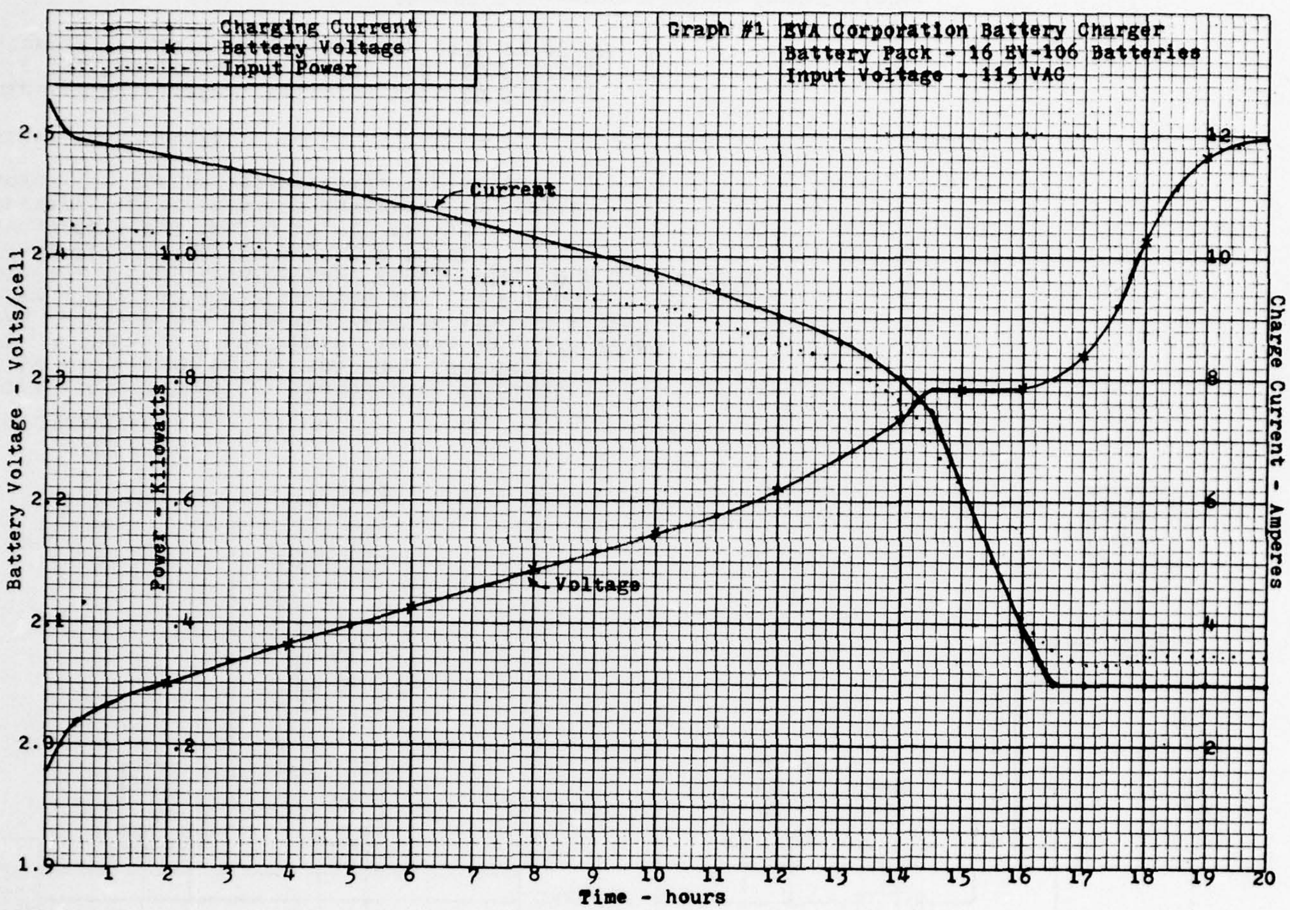


Figure E7. Battery Charger Current and Voltage Slopes.

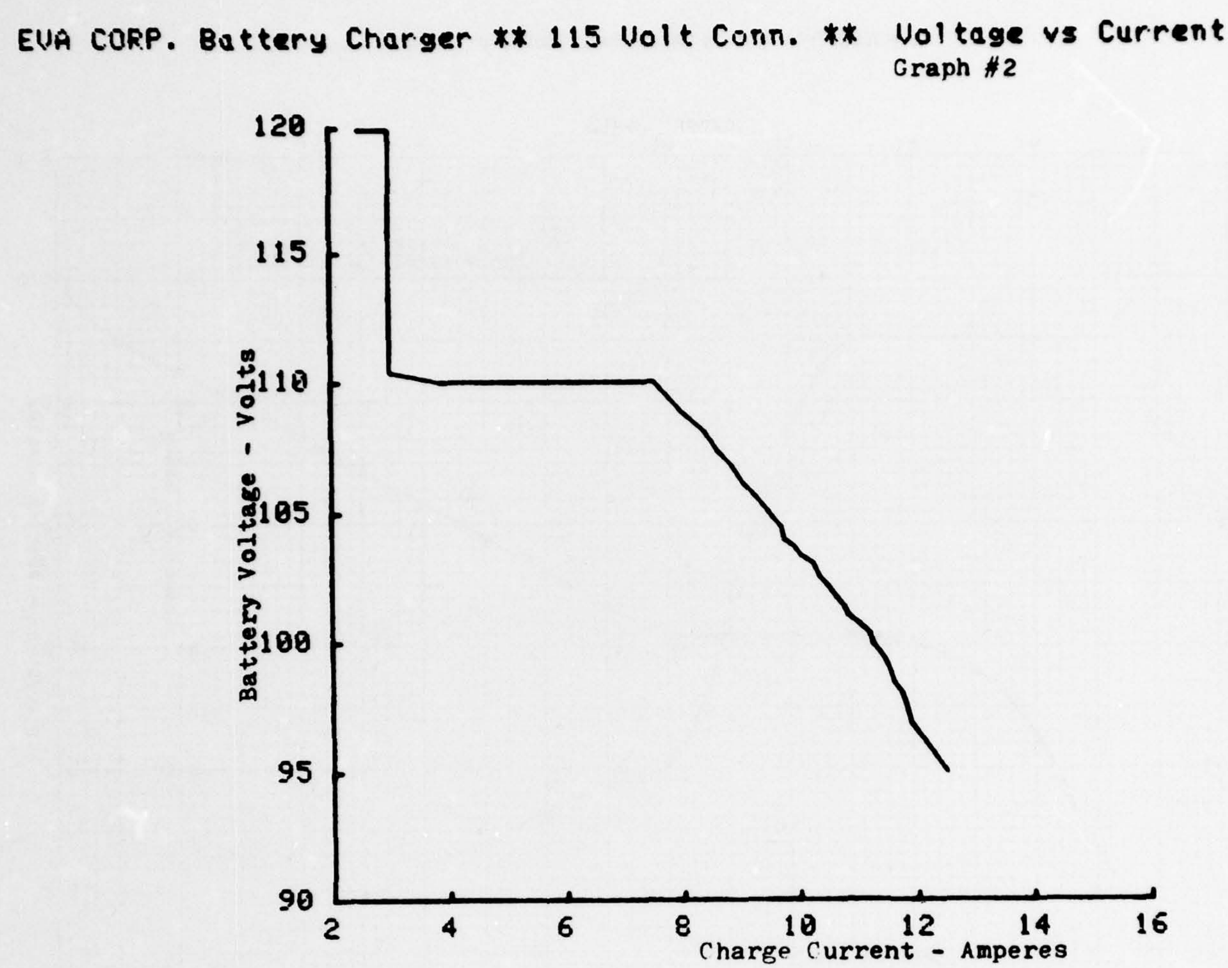


Figure E8. Battery Charger Voltage/Current Slope, Graph 2.

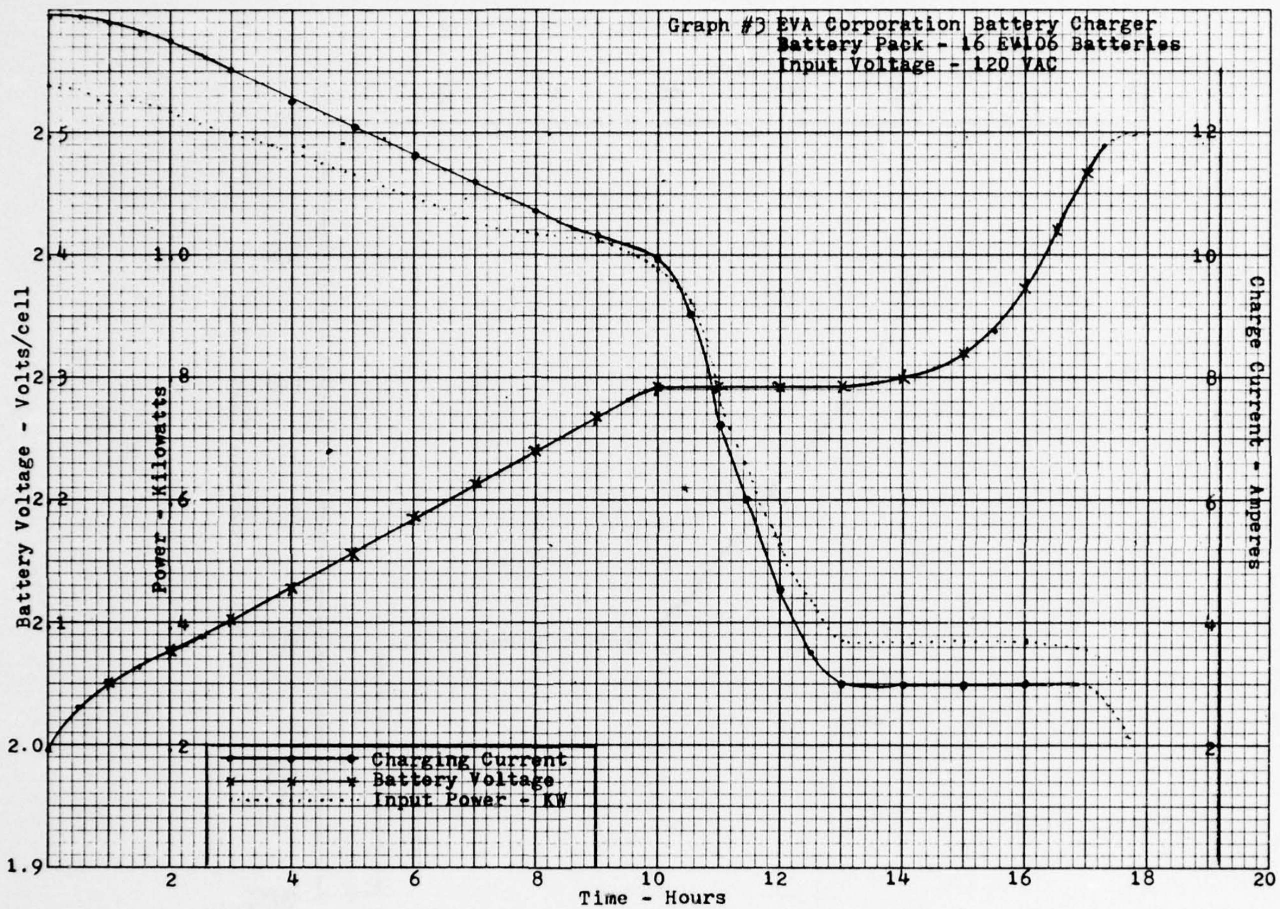


Figure E9. Battery Charger Power Consumption, 120 V RMS.

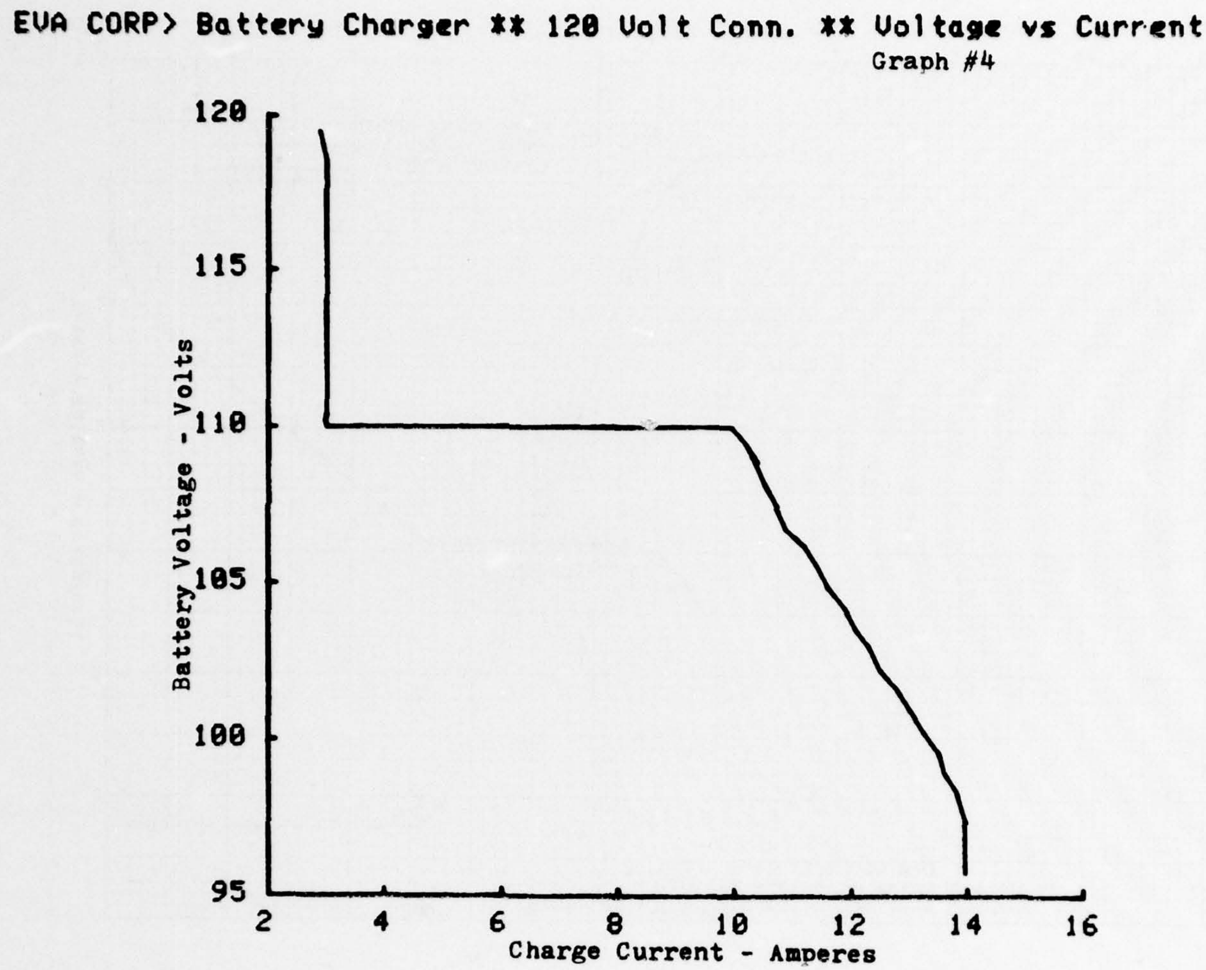


Figure E10. Battery Charger Voltage/Current Slope, Graph 4.

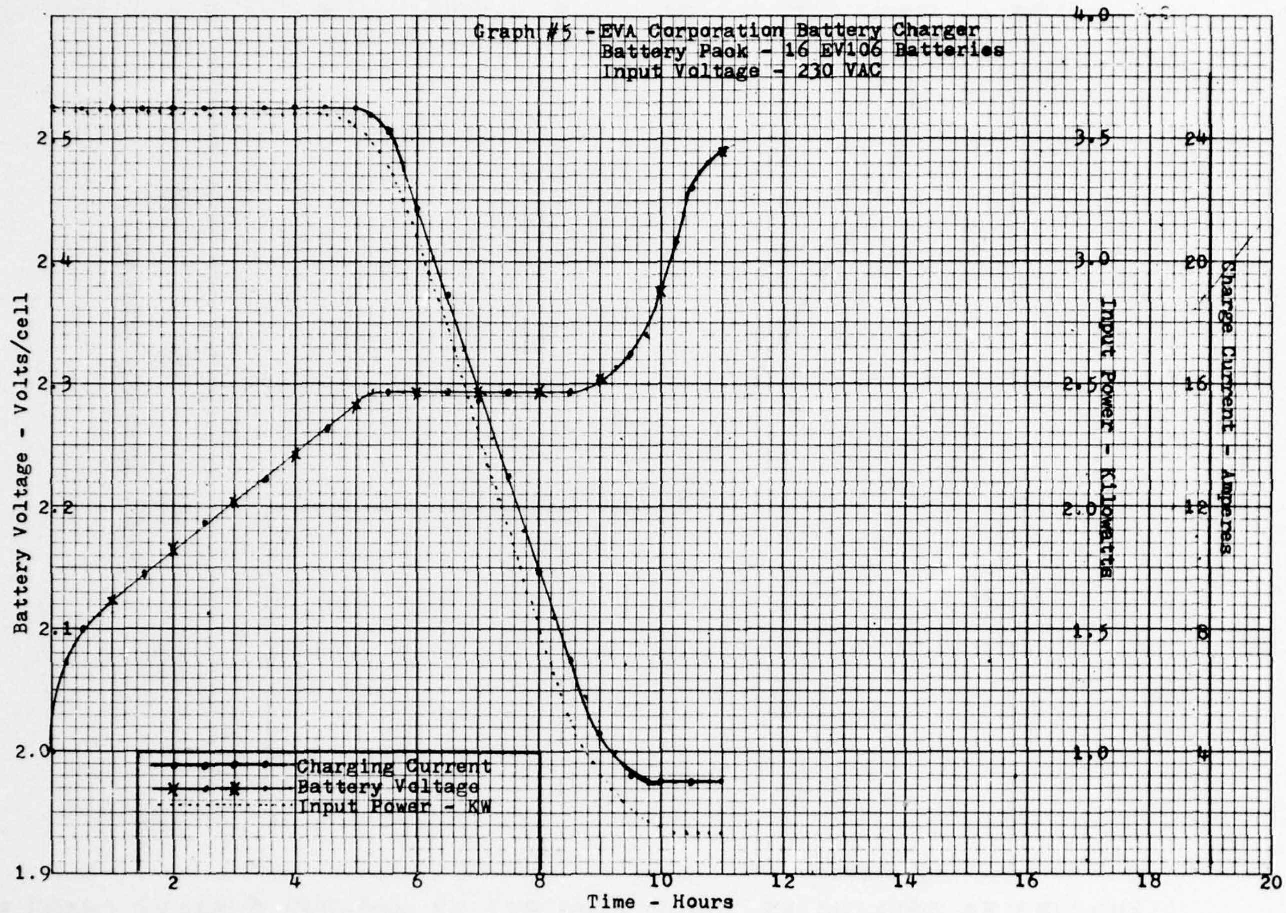


Figure E11. Battery Charger Power Consumption, 240 V RMS.

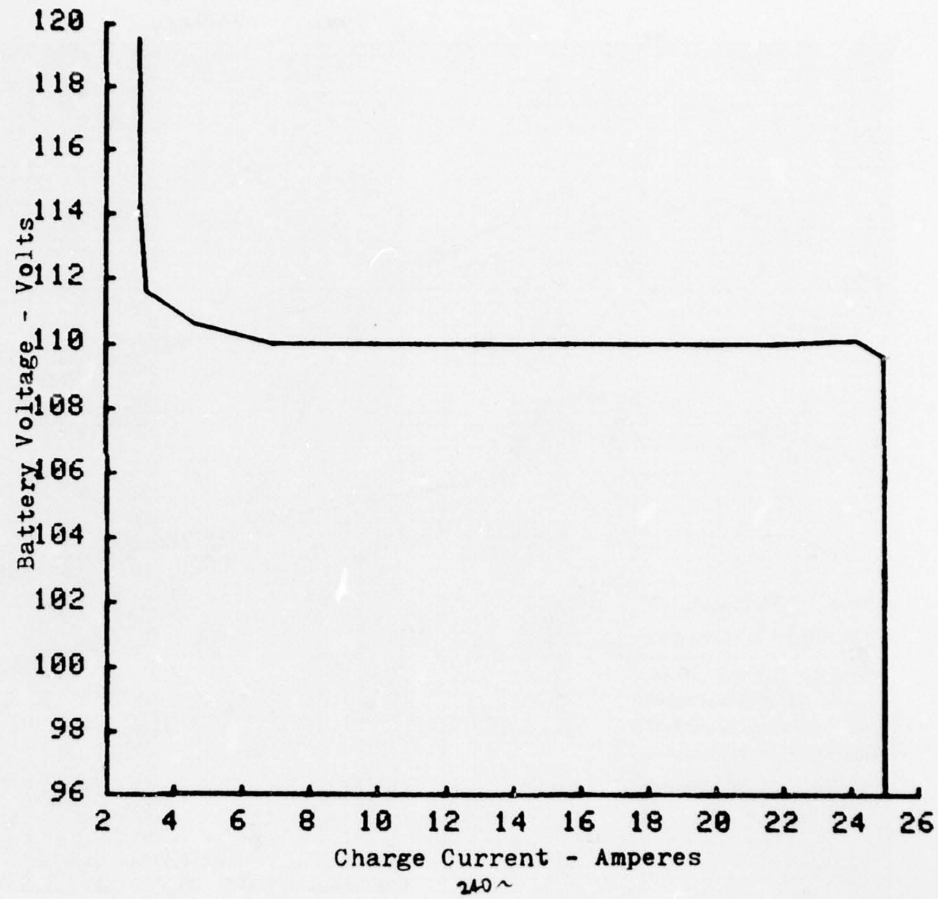


Figure E12. Battery Charger Voltage/Current Slope, 240 V RMS.

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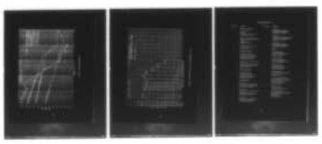

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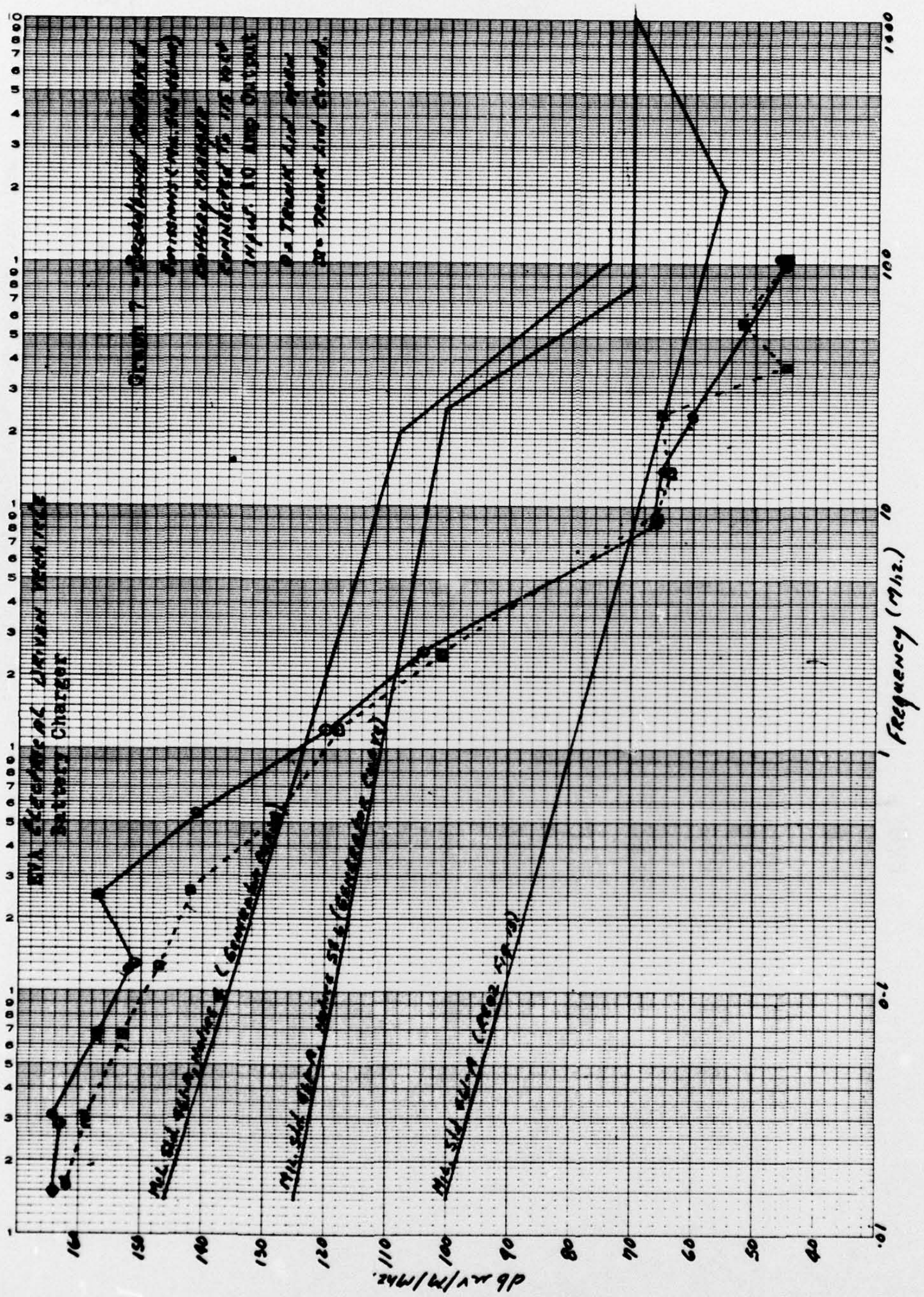

Figure E13. Broadband Radiated EMI.

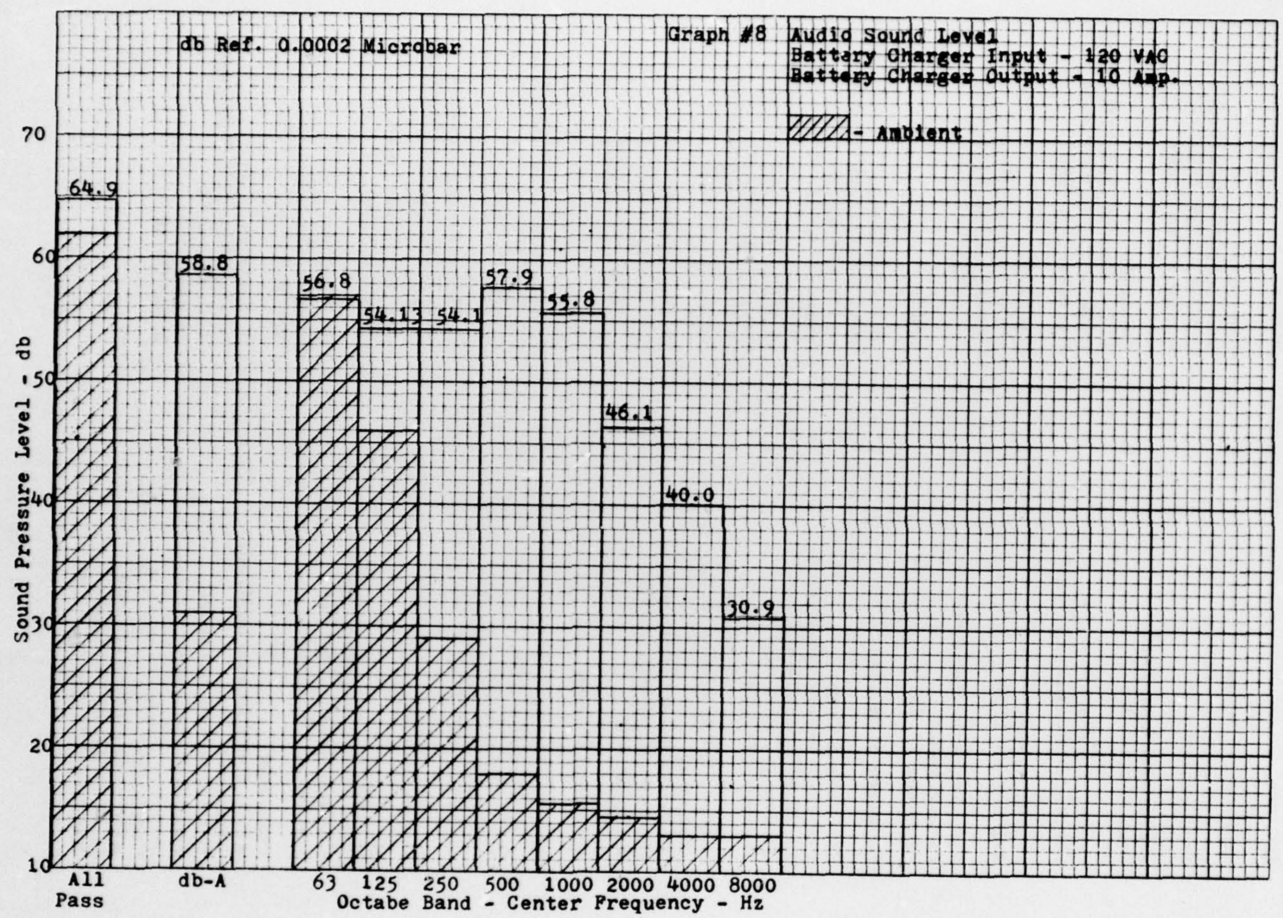

Figure E14. Audio Sound Level: Input – 120 V RMS; Output – 10A.

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